Organ Pipe Cactus National Monument Ecological Monitoring Program Annual Report 1994

The Division of Natural and Cultural Resources Management
Organ Pipe Cactus National Monument

United States Department of the Interior
United States Geological Survey
Cooperative Park Studies Unit
The University of Arizona

and

National Park Service
Organ Pipe Cactus National Monument

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May 1998

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The Cooperative Park Studies Unit at The University of Arizona (CPSU/UA) was established 16 August 1993 as a unit in the National Park Service (NPS). By action of Secretary of the Interior Bruce Babbitt, the research function of NPS and several other Interior agencies was transferred to a newly created agency, the National Biological Service (NBS), on 12 November 1993. At that time, the CPSU/UA and unit personnel were transferred to the new agency. On 1 October 1996, NBS became the Biological Resources Division of the U.S. Geological Survey (USGS).

As the nation's largest water, earth, and biological science and civilian mapping agency, the USGS works in cooperation with more than 2,000 organizations across the country to provide reliable, impartial, scientific information to resource managers, planners, and other customers. This information is gathered in every state by USGS scientists to minimize the loss of life and property from natural disasters, contribute to sound economic and physical development of the nation's natural resources, and enhance the quality of life by monitoring water, biological, energy, and mineral resources.

The CPSU/UA provides a multidisciplinary approach to studies in natural and cultural sciences. The unit conducts and coordinates research that is funded by various agencies.

Principal Arizona cooperators include the School of Renewable Natural Resources and the Department of Ecology and Evolutionary Biology of The University of Arizona. The Western Archeological and Conservation Center (NPS) and the School of Renewable Natural Resources (UA) provide administrative assistance. Unit scientists hold faculty or research associate appointments at the university.

The Technical Report series allows dissemination of information about high priority resource management questions. The series allows the flexibility of retaining considerable information on study design, methods, results, and applications not afforded in formal scientific publications. Technical reports are given peer review and editing. Documents in this series usually contain information of a preliminary nature and are prepared primarily for use by USGS personnel and cooperators. Mention of trade names or commercial products does not constitute endorsement or use by USGS.

Reports in this series are produced in limited quantities. As long as the supply lasts, copies may be obtained from the Cooperative Park Studies Unit, USGS–CPSU/UA, 125 Biological Sciences East. The University of Arizona, Tucson, AZ 85721.

*This list does not include personnel who contributed to the Ecological Monitoring Program in 1994 but no longer work at Organ Pipe Cactus National Monument: Harold J. Smith (Superintendent), James J. Barnett (Chief, Resources Management), and Jonathan F. Arnold (Ecologist).

This report was printed on recycled paper.

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Introduction

Organ Pipe Cactus National Monument (ORPI), established in 1937, is located in southwestern Arizona and is geographically near the center of the Sonoran Desert. The monument encompasses 133,830 ha, of which 95% is designated wilderness. On 26 October 1976, the United Nations Education, Scientific, and Cultural Organization (UNESCO) recognized and designated ORPI as a biosphere reserve. Although the monument includes only a small portion of the vast Sonoran Desert, it preserves many elements of that ecosystem. The monument encompass not only mountain ranges, but also rich habitats of bajada, valley floor, riparian systems, and expanses of arid creosotebush plains. Although originally conceived as a monument to preserve a unique species of columnar cactus, ORPI now stands as one of the most diverse protected areas of the Sonoran Desert ecosystem in the United States or Mexico.

Like other natural preserves, ORPI is vulnerable to rapidly changing land uses outside monument boundaries. Of special concern is the southern boundary, which borders the neighboring state of Sonora, Mexico. In the late 1960s, the Mexican government encouraged and subsidized agricultural development in the Sonoyta Valley, where previously only subsistence farming had been practiced. Approximately 165 wells were serving 12,950 ha by 1988. Although a moratorium on the construction of new wells is now in effect, groundwater depletion in the Sonoyta Valley aquifer is a constant threat, as current capacity for water withdrawal is twice the rate of recharge (Great Western Research 1988). Other concerns to ORPI include the effect of herbicide and pesticide drift on native plants and animals, increased vehicle traffic, and the invasion of nonnative flora and fauna. With the recent passage of the North American Free Trade Agreement, increased urbanization, agricultural development, and manufacturing have become new threats to desert ecosystems in the monument.

Sensitive Habitats Project

With growing outside threats to the monument in the 1980s, park managers recognized the need to initiate a program that could provide insight about the condition of the ecosystem at ORPI. The first set of projects to meet this goal was known as the Sensitive Habitats Project, proposed in 1985. This project stemmed from 4 high-priority research projects identified in the 1984 Resource Management Plan: (1) Effects of Mexican Agriculture on ORPI Ecosystems, (2) Inventory of ORPI Herpetofauna, (3) Survey of ORPI Insect Fauna, and (4) Climatological Monitoring. These projects were later combined beneath the holistic proposal "Changes in Sonoran Desert Ecosystems at Organ Pipe Cactus National Monument with Reference to Sensitive Habitats." Monument habitats were considered sensitive because many plant and animal species occurring there were near the edge of their geographical distribution limits, thus subject to greater stresses and more rapid changes than elsewhere.

Sensitive Ecosystems Program

In 1986, an international panel of scientists, resource managers, and administrators was convened to design a much larger integrative program. The new program was called the Sensitive

Ecosystems Program (SEP), and it encompassed numerous projects, including the former Sensitive Habitats Project.

Modelled after the successful Channel Islands Inventory and Monitoring Initiative, step-down planning was used to efficiently organize the management goals and objectives of the program. Step-down planning requires a single-purpose primary objective that communicates the identity and nature of the problem to be addressed. After the primary objective is defined, all sequential steps necessary to accomplish this objective, in order from large to small, are identified. In this way, attention is focused on the primary management objective, and only actions needed to attain this objective are considered.

The primary objective for the SEP was to develop a management program to determine (1) the condition of ORPI ecosystems, (2) alternatives available for ecosystem management, and (3) the effectiveness of implemented action programs. Steps identified to support this objective included policy review, surveys and investigations of many ecosystem components, long-term monitoring protocols, and the development of an information management system.

By 1988, baseline research associated with 12 studies was under way. Summaries of these studies follow. By 1991, base funding increases had allowed the monument to bring on a minimal staff to implement recommended long-term monitoring protocols associated with the original research projects. A critical element during the research phase was that resource management staff worked extensively with the principal investigators in the field. The protocols have been tested and refined as a result of the feedback loop between researchers and field staff.

Land Use Trends Surrounding Organ Pipe Cactus National Monument
In this study, Bruce Brown determined the current uses of adjacent lands, with particular emphasis on the Rio Sonoyta Valley in Sonora, Mexico. Acreage in agricultural production, types of crops raised, and associated acreage and annual groundwater pumpage rates were determined during this project.

Inventory and Assessment: Special Status Birds
R. Roy Johnson designed this study to provide information about the distribution and relative abundance of birds, with special emphasis on the breeding birds in the vicinity of the SEP study sites.

Inventory and Assessment: Terrestrial Invertebrates
Kenneth J. Kingsley attempted to determine the important invertebrate species ecosystem and identify indicator species and their relationship to that ecosystem. Approximately 4,200 invertebrate specimens were added to the invertebrate collection at the monument.

Inventory and Assessment: Amphibians and Reptiles
This study was designed by Charles H. Lowe to provide information about reptile and amphibian species occurrence, distribution, and relative abundance. Criteria were established and lizard

species selected to monitor as indicators of herpetofaunal health in the long-term monitoring effort.

Inventory and Assessment: Nonnative Vegetation

Richard Felger identified 62 species of vascular plants, located in or adjacent to the monument, as being possibly nonnative. Nonnatives represent about 11% of the park flora, which may be an over-estimation because (1) some "nonnatives" may actually be native, (2) some species are present but not reproducing, and (3) some are in adjacent Sonora but have not been seen in the monument.

Inventory and Assessment: Special Status Mammals

The intent of Yar Petryszyn's study was to provide information about species distribution and relative abundance of monument mammals. Criteria were established for selection of mammal indicator species, and nocturnal rodents were selected to be monitored.

Inventory and Assessment: Special Status Plants

In this project, designed by George Ruffner, a detailed study was made of 17 unique or vulnerable plant species to determine regional distribution, abundance, and factors that limit distribution. In addition, the project assessed impacts and threats to the plants and provided recommendations for management. Long-term monitoring protocols were designed for 4 of the 17 plant species.

Recovery of Monument Ecosystems since Termination of Cattle Grazing

In 1977, shortly before the removal of cattle, vegetation plots and photo points were established to gather baseline data on ecosystem recovery response to the removal of cattle, and associated impacts. Peter Warren reread these existing vegetation plots and rephotographed the photo points. In addition, nocturnal rodent populations were resampled on the monitoring plots, and relationships between the distribution of rodents and the amount of vegetative cover established.

Climatological Monitoring

Nine automated weather stations were installed near SEP study sites by ORPI resource management staff. A combination of the following parameters are measured at the sites: precipitation, relative humidity, wind speed and direction, air temperature at 2 heights, soil temperature, and solar radiation. This project was designed to provide an important integrative link between all the SEP projects.

Vegetation Community Patterns on the Boundaries of Organ Pipe Cactus National Monument

Peter Warren examined and documented plant community patterns along the park boundary to determine the cross-boundary effects of changes outside the monument on plant communities within the monument. Patterns of plant community composition and distribution within 2 km of all boundaries were examined.

Vegetation Structure and Diversity in Natural Communities

In this project, Charles H. Lowe focused on collecting information on vegetation structure and diversity rather than on plant population dynamics, plant growth, phenology, productivity, plant interactions, and so forth. Presence, density, frequency, coverage, and diversity of perennial plants were measured on 0.1-ha permanent quadrats located at each SEP study site. The same parameters were measured for ephemeral plant species on 1.0-m^2 quadrats. Quantitative data from this study and the resulting long-term monitoring protocols will provide both intersite variation and intrasite change in composition, structure, and diversity of plant species.

Treaties, Agreements, and Accords Affecting Natural Resource Management at Organ Pipe Cactus National Monument

Carlos Nagel compiled the treaties, legal agreements, and memoranda of understanding made between the United States and Mexico that affect the management of natural resources in and around the monument, and provided a mechanism for keeping this information current.

Ecological Monitoring Program

In spring 1994, the title SEP was changed to the Ecological Monitoring Program (EMP) to reflect a change from the historic focus on "sensitive" areas to a broader look at the ecosystem's many components. As a result of the EMP, ORPI has the framework for one of the most extensive ecological research and inventory and monitoring programs in the National Park Service (NPS). The methodologies and tools for long-term monitoring provided by the scientists will provide park managers with the "vital signs" of the monument ecosystem.

Though still a young program, the EMP has already affected monument management. Development of the ORPI General Management Plan and Resources Management Plan has been influenced by the inventory of resources. Cooperative resource management efforts have been developed with neighboring land-management agencies. Contacts have been established with resource counterparts in Sonoyta, Sonora, Mexico, and data are shared on land-use trends, water usage and development, pesticide and herbicide use, and other concerns.

Information Management

After 8 years of baseline data acquired as part of the EMP, the integration and synthesis of results have been initiated. Key components in the synthesis of ecological data are database management systems (DBMS) and geographic information systems (GIS). A GIS database is already in place, and new cooperative agreements and proposals will shape the future links between monitoring data and predictions on the status of resources. The GIS database is currently being expanded to include detailed information on each monitoring site.

A regional prototype, the proposed Northern Sonoran Desert Ecological Monitoring Model (NSDEMM) will be able to make predictions on the status of resources and assist resource managers in establishing future monitoring and research sites. In this model, the DBMS will link tabular information to the GIS database and will integrate diverse inventory and monitoring data sources into a single framework.

Ecological Monitoring Program Assistance Committee (EMPAC)

In October 1993, the first EMPAC meeting was held. The advisory team, a mix of scientists and managers, was convened to provide an ongoing evaluation and assessment of activities associated with the ecological inventory and monitoring program at ORPI, and to direct progress towards the synthesis of the program. Committee activities include assessing the history of the program and providing guidance for future direction, examining and critiquing completed research and monitoring protocols, providing recommendations for future baseline studies and advanced specialized research, evaluating results of current monitoring (and suggesting modifications, if needed), developing strategies for integration and synthesis, and examining alternative methods for data management and linkages with GIS.

In 1994, the committee met 4 times. A February meeting provided an opportunity for EMPAC members to interact with the ORPI resource management field staff and discuss elements of the monitoring program. Staff presented overviews of the monitoring protocols and initiated discussions on changes or additions needed to enhance the program. The committee also discussed methods for incorporating larger mammals into the monitoring program. Other 1994 meeting topics included information management, evaluation of EMP study sites, and publication of protocols and final reports.

Ecological Monitoring Program Study Site Descriptions

The majority of SEP and EMP research was conducted at 16 select study sites (Fig. 1). Sites ranged in size from 2.5 to 126 ha. Sites were selected to meet the goal of representing the various ecological communities of the monument. In addition, some sites on the south boundary were selected to monitor impacts from agricultural development and urbanization on adjacent Mexican lands. Priority sites for future monitoring were identified by SEP researchers and were divided into 4 groups (cores) based on the level of importance for monitoring. Since the original research projects, new sites have been added to the program.

At a 1994 EMPAC meeting, the sites were evaluated in terms of habitat representation, redundancy, logistics, and monitoring data collected to date. The committee decided that 2 habitat types lacked representation: middle bajada and valley bottom. Two new study sites in those habitats were chosen and in 1995 added to the monitoring program. The following study site descriptions are broken into the current core designations. At Core I sites, the full monitoring program is implemented. These sites contain bird and lizard transects, vegetation quadrats and nocturnal rodent grids and have an automated climate station either on site or nearby. Non-Core I sites have second priority in the monitoring program, and only rainfall data are collected at most of these sites.

Core I Sites

Aguajita

Elevation ca. 735 m. This site incorporates Aguajita Wash and adjacent uplands. Aguajita Wash is a large wash that drains much of the south half of the monument. *Prosopis velutina* riparian woodland and *P. velutina—Cercidium floridum* subassociation are the 2 main vegetation types. *Atamisquea emarginata* reaches its northern geographic limits here. The upland sites are dominated by an *Atriplex polycarpa—Atriplex linearis—Prosopis velutina* subassociation.

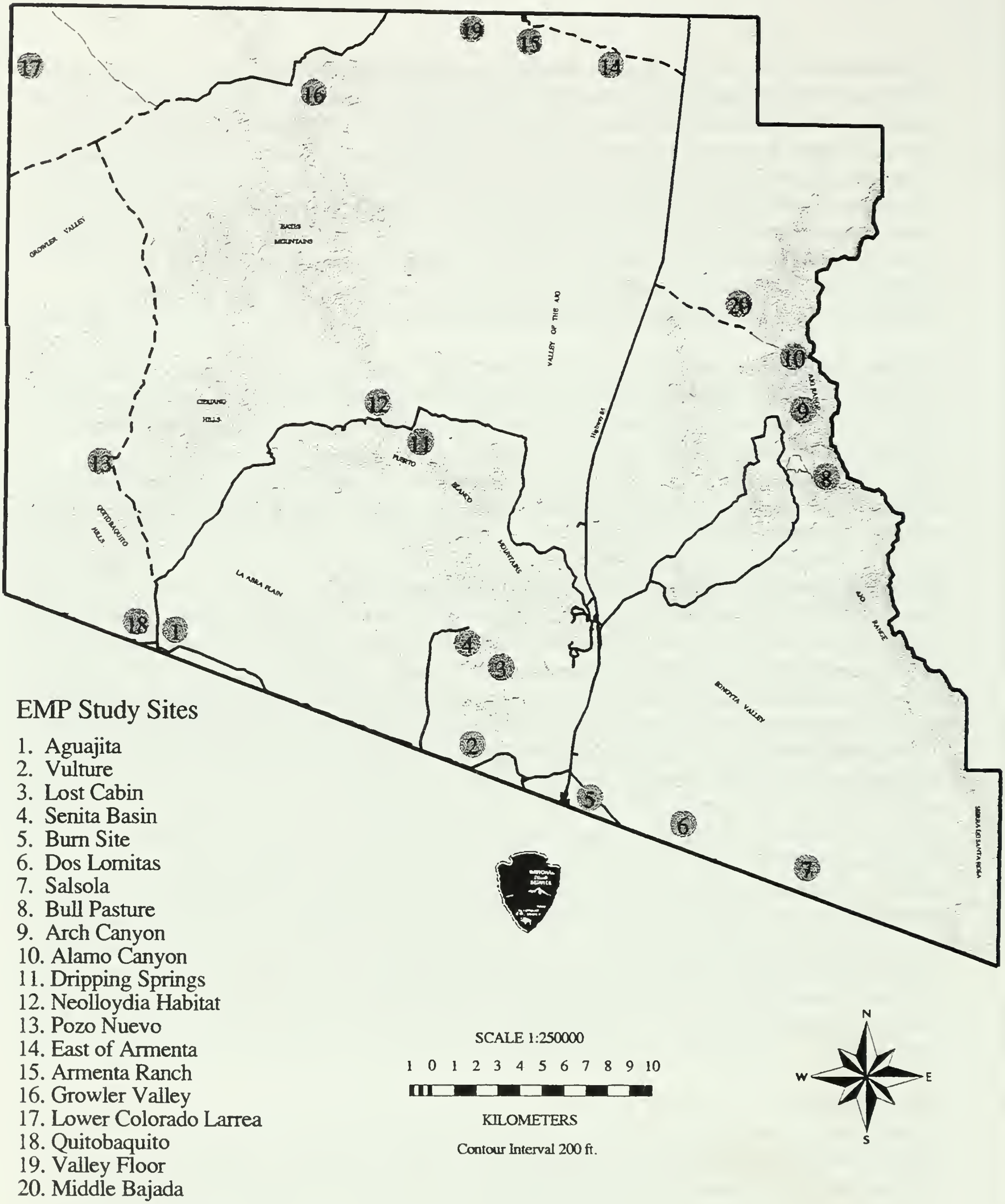


Figure 1. Map of Ecological Monitoring Program study sites in Organ Pipe Cactus National Monument.

Alamo Canyon

Elevation ca. 900 m. This site is located in a steep, narrow canyon dissecting the Ajo Mountains. Soil is sandy with scattered cobbles and large boulders. *Quercus turbinella* var. *ajoensis* (= *Q. ajoensis*) mixed scrub subassociation, with *Vauquelinia californica, Acacia greggii,* and *Simmondsia chinensis* are characteristic species in the riparian zone. Upland species diversity is high due to the relatively mesic environment, diverse surrounding habitats and topographic relief.

Dos Lomitas

Elevation ca. 487 m. This site is adjacent to the International Boundary, east of Lukeville. Livestock grazing and other environmental disturbances have occurred at this site in the past, causing plant community collapse and severe soil erosion. The vegetation association prior to this degradation is unknown, but probably included *Atriplex polycarpa, Atriplex linearis, Larrea tridentata,* and *Prosopis velutina.* These species are currently colonizing the area.

East Armenta

Elevation 480 m. This nearly level site supports a *Larrea tridentata—Pleuraphis rigida—Prosopis velutina* floodplain subassociation on a sandy loam. Erosion has cut a few gullies in the vicinity of the site but may not have significantly lowered the water table yet.

Growler Canyon

Elevation ca. 420 m. This site is located in a wide canyon that trends east to west in the northern end of the Bates Mountains. Groundwater is near the surface because of the confluence of 2 large washes just east of the canyon. Soil is deep, silty, and easily detached. The vegetation is *Prosopis velutina* riparian woodland subassociation. The area has one of the longest-documented histories of overuse by livestock anywhere in the monument.

Lower Colorado Larrea

Elevation ca. 335 m. This site is located in the northwest corner of the monument, near the boundary of the Cabeza Prieta National Wildlife Refuge. It contains fine, silty soils with a *Larrea tridentata—Ambrosia dumosa* vegetation subassociation.

Middle Bajada

Elevation ca. 630 m. This new Core I site is located on the middle bajada of the western-facing slope of the Ajo Mountains, to the north of the Alamo Canyon Road. The vegetation on the slopes is an *Ambrosia deltoidea—Cercidium microphyllum*—mixed cactus association. The bajada is deeply dissected by drainages, which are lined with xeroriparian zones dominated by *Acacia constricta, Cercidium microphyllum, Simmondsia chinensis, Lycium berlandieri*, and *Brickellia coulteri.* The site is nearly level, sloping slightly to the northwest. The soil is in the Cipriano Series, a very gravelly loam underlain by a duripan.

Pozo Nuevo

Elevation ca. 380 m. This site is located near the western boundary of the monument, and is situated on fine sandy loam and cobbley sandy loam soils. The vegetation classification is *Larrea tridentata—Ambrosia dumosa* association.

Senita Basin

Elevation ca. 510 m. This site includes a north-facing slope, a south-facing slope, and level ground. It remains frost-free most of the year. The vegetation types are the 3 most frost sensitive: *Cercidium microphyllum—Encelia farinosa—Stenocereus thurberi—Jatropha cuneata* hillside subassociation, *Cercidium microphyllum—Encelia farinosa—Stenocereus thurberi—Bursera microphylla* subassociation, and *Cercidium microphyllum—Ambrosia deltoidea—Cereus thurberi* with *Jatropha* spp. subassociation. Soils vary from deep alluvium to bare rock.

Valley Floor

Elevation ca. 450 m. This new Core I site is located in the Valley of the Ajo and encloses one channel of Kuakatch Wash. This and other drainages in the area are shallow, and during the summer floodwaters often breach channels. The soil at the site is a deep and well-drained, very fine, sandy loam in the Gilman Series. The vegetation along the channels is dominated by *Prosopis velutina, Olneya tesota*, and *Cercidium microphyllum,* with a prominent vine component (*Clematis drummondii, Sarcostemma cynanchoides, Aristolochia watsonii*). Areas between drainages are dominated by *Larrea tridentata, Muhlenbergia porteri,* and annuals. *Dipodomys deserti* (desert kangaroo rat) plays an important role in patterning the latter plant association.

Non-Core I Sites

Arch Canyon

Elevation ca. 915 m. Arch Canyon is a west-facing canyon located in the Ajo Mountains. One perennial vegetation quadrat is located on a steep, north-facing drainage in a rocky side canyon below the arch. Vegetation is characterized by dense thickets of large sclerophyllous shrubs, 1–2 m in height. The dominant shrub is *Simmondsia chinensis*. The other vegetation quadrat is located across the canyon on a steep slope with a southern exposure. The dominants on this quadrat were various grass species, *Simmondsia chinensis, Ambrosia deltoidea, A. cordifolia*, and *Encelia farinosa*.

Armenta Ranch

Elevation ca. 480 m. This site is located on a severely degraded site that was acquired by the NPS in the 1970s. Prior to its incorporation in the monument, the area was overgrazed for decades, vegetation was cleared for housing and farming, and fuelwood was harvested. These uses led to the severe erosion that continues today. The water table is presumed to have dropped dramatically due to gullying, resulting in the widespread death of deep-rooted plants. The soil is classified as a Gilman Series sandy loam. The vegetation subassociation is *Larrea tridentata—Prosopis velutina* floodplain.

Bull Pasture

Elevation ca. 920 m. This site is located on a mid-elevation bench below the higher peaks of the Ajo Mountains, at the headwaters of Estes Canyon. The area is dissected by 2 drainages, one shallow without permanent water and the other deeper and fed by a spring. Soils are very shallow and rocky. The vegetation subassociation is *Simmondsia chinensis—Viguiera deltoidea—*

Fouquieria splendens. Subassociations vary depending on the slope and exposure. *Juniperus coahuilensis* is found in drainages.

Burn Site

Elevation ca. 420 m. This severely disturbed site is situated near the International Boundary east of Lukeville. The area was severely overgrazed until 1979, and various soil erosion control structures were built in the 1950s to 1960s. The recovering vegetation burned in 1983. The potential plant association throughout most of the site was probably dominated by *Larrea tridentata, Ambrosia deltoidea, Atriplex polycarpa*, and *Atriplex linearis.*

Dripping Springs

Elevation ca. 650 m. This site is located in a steep, north-facing mountain slope with thin, rocky soil derived from lava and tuff. Subsurface moisture is abundant locally, especially on tuff deposits. Free water, of low salinity, is found in several caves. Characteristic species include *Simmondsia chinensis, Coursetia glandulosa, Viguiera deltoidea*, and *Fouquieria splendens.*

Lost Cabin

Elevation ca. 500 m. This site incorporates floodplain and upper rocky slope habitats. Like the nearby Senita Basin EMP site, it is frost-free most of the year. The vegetation association is *Cercidium microphyllum—Ambrosia deltoidea—Stenocereus thurberi—Jatropha* spp.

Neolloydia Habitat

Elevation ca. 500 m. This site includes habitat for the rare cactus *Echinomastus erectocentrus* var. *acuñensis*. The plants occur on level, north-, or south-facing slopes of several small hills near the north pediment of the Puerto Blanco Mountains. The cactus is confined to a habitat nearly devoid of soil, and the plants prefer to grow in cracks in the fractured granite bedrock. The vegetation association is *Ambrosia deltoidea—Cercidium microphyllum* pediment subassociation.

Quitobaquito

Elevation ca. 330 m. This site incorporates a spring-fed channel and pond surrounded by a mesquite bosque with a dense shrub layer consisting mostly of *Lycium fremontii.* The littoral zone around the perimeter of the pond is occupied by *Scirpus americanus.* Surrounding the mesquite bosque is a plant association dominated by *Atriplex polycarpa, Atriplex linearis*, and *Suaeda moquinii* (= *S. torreyana*). *Pluchea sericea* dominates the spring heads, and *Distichlis spicata* carpets the salty, wet, open areas. This diverse system continues to recover from past human occupation and livestock grazing.

Salsola

Elevation ca. 500 m. This site is located adjacent to the International Boundary on silty floodplain soil, *Larrea tridentata—Ambrosia* spp. subassociation and *Larrea tridentata—Prosopis velutina* floodplain subassociation. The understory in the floodplain is dominated by the weedy nonnative plants *Salsola australis* and *Amaranthus palmeri.* The composition of this

community has been profoundly altered by erosion, nonnative plants, and past overgrazing and woodcutting.

Vulture

Elevation ca. 450 m. This site is located adjacent to the International Border on sandy cobbley soil. It lies on the bajada of the Sonoyta Mountains and is transversely dissected by a fourth order wash. The site was named after a colony of roosting black vultures *(Coragyps atratus)*, a species that is at its northern range limit in southern Arizona. Along the shallow wash channels, the xeroriparian plant community is dominated by *Cercidium microphyllum, Olneya tesota,* and a diversity of shrubs and sub-shrubs. Outside the narrow riparian corridor, the vegetation is dominated by *Larrea tridentata* and *Ambrosia deltoidea.*

Ecological Monitoring Program Annual Report

Annual reports of the ORPI EMP will summarize monitoring activities completed and data collected. They will follow a similar format from year to year to easily provide comparisons. For each monitoring protocol, the following will be provided: introduction, project history, summary of monitoring activities, methods, and results. Simple data summaries in tabular and graphic format will also be provided.

In the 1994 annual report that follows here, monitoring activities are divided into 3 sections: (1) vegetation, (2) wildlife and (3) climate, air quality, land use trends, and groundwater. Table 1 shows the hours spent in each monitoring activity.

Results from 1994 monitoring of Vegetation Structure and Diversity perennial vegetation plots will be summarized in future EMP annual reports.

Table 1. Hours spent by Organ Pipe Cactus National Monument staff and volunteers in Ecological Monitoring Program projects during 1994.

Activities	Hours
Field Monitoring	
Weather stations and raingauges	302
Perennial plant monitoring	296.5
Nocturnal rodent monitoring	296
Acuña monitoring	240
Lizard monitoring	213.5
Bat monitoring	131
Air quality (NADP, etc.)	111.5
Bird monitoring	107.5
Land use trends photos	64
Leptonycteris curasoae monitoring	63.5
Quitobaquito desert pupfish	62.5
Stenocereus thurberi/Lophocereus schottii growth	61.5
Groundwater measurements	47
Atamisquea emarginata monitoring	10
Peniocereus striatus monitoring	6
Total	2012.5
Administrative	
Data entry and report writing	487
Assistance committee	167
Miscellaneous administration	84.5
Total	738.5

Acuña Cactus

Introduction
Organ Pipe Cactus National Monument contains 1 of only 4 known populations of acuña cactus (*Echinomastus erectocentrus* var. *acuñensis).* Since 1988, this cactus has been monitored for growth, reproduction and mortality. Data gathered in this project will aid in gaining an understanding of population dynamics and the relationship between rainfall and patterns of mortality and establishment.

Project History
In the late 1970s, William Buskirk and students from Earlham College developed a protocol to monitor acuña cacti at ORPI, primarily to detect theft of the highly valued cactus. Although these monitoring efforts brought a greater knowledge and understanding of the species, much remained unknown concerning its basic biology and population dynamics. Meanwhile, the unexplained serious decline of the other 2 acuña populations in Arizona (the fourth population occurs in Sonora, Mexico) prompted the U.S. Fish and Wildlife Service (USFWS) to declare the cactus a Category 1 candidate species for listing consideration as a threatened plant. To make sound decisions regarding the implementation of the Endangered Species Act, however, USFWS must have access to sound biological knowledge of taxa being considered for listing, as well as adequate information on demographics.

This knowledge is presently being obtained as a result of the upgraded acuña monitoring protocol developed during the SEP project entitled *Special-status Plants of Organ Pipe Cactus National Monument* (Ruffner Associates 1991). This protocol was designed to collect more complete demographic data for the plant. Monitoring efforts using this protocol began in 1988 and have continued annually. The data collected during this time have already contributed to a paper by the principal investigators: "Seedling Establishment, Mortality and Flower Production of the Acuña Cactus" (Johnson et al. 1993).

1994 Monitoring Activities
The acuña monitoring protocol was implemented from 28 February to 2 March and again on 22 March and 31 March by personnel from the Division of Natural and Cultural Resources Management and by several volunteers. Special-status plants co-investigators Robert Johnson and Marc Baker assisted during the monitoring effort. This monitoring included measuring all tagged plants, counting flowers and buds and searching for new seedlings.

Methods
The 28 February–2 March field activities consisted of locating and measuring all previously tagged and mapped individuals on the 6 permanent plots of 0.1 ha each. At the same time, an intensive and systematic search was made within these plots to locate additional plants—plants that, in estimation, had germinated since the last monitoring activity ("new"), or plants that, in estimation, had in fact been alive but escaped detection during the 1992 monitoring session ("old"). This very intensive search was facilitated by cordoning off the 0.1-ha plots (20 x 50 m)

into 2 x 20-m subplots using non-stretchable tape measures. All newly found plants were measured, tagged, and given an X and Y coordinate value relative to the 0 x 0-m corner point of the plot.

Reproductive condition of the plants was assessed later, at the peak of flowering. Flower/bud counts were made on 22 March and 31 March, and the higher of the 2 counts for the individual plants was used to assess reproductive effort.

Results

The annual mortality rate of the seedlings and small size classes was lower in 1994 than in 1993. In 1994, 26 out of 102 plants in the 1 to 10-mm size class died, while in 1993 mortality was 46 out of 109 plants in the same size class (Table 2). The 11 to 20 and 21 to 30-mm size classes show a similar decrease in mortality. These younger, less well-established plants are more vulnerable to adverse weather conditions. Figure 2 summarizes rainfall data, 1989–1994. Heavy rains in August 1993 probably helped some plants survive the summer.

Few new seedlings were found this year. This was probably due to the poor 1993 summer rains (the principal germination season is after summer monsoon rains). However, some very small new seedlings were found that probably had germinated from the winter/spring rains in 1994. Acuña size distribution is summarized in Table 3 and Figures 3 and 4.

Reproductive effort was less in 1994 than in 1993, also probably due to low rainfall. Both the figures for the average number of flowers and the percentage of plants with flowers were down, except for the largest size classes. Acuña reproductive condition is summarized in Figures 5–7.

A poaching incident was detected during the 1994 monitoring. Between the 22 March and 31 March flower/bud counts, 2 plants on plot #0 were taken.

Data from the 1994 acuña monitoring season are summarized in table and chart form on the following pages. Although both width and height measurements are taken in the field, size classes are based upon height only. Table 2 summarizes the number of individuals per size class for 1994 and the number of plants with flowers in those size classes, as well as the mean height growth from 1993 to 1994 and mortality. The frequency figures for growth and mortality are based upon the previous year size classes and thus differ from the 1994 absolute frequency figures.

Table 2. Acuña cactus (*Echinomastus erectocentrus* var. *acuñensis*) reproduction, growth, and mortality at Organ Pipe Cactus National Monument, Arizona, 1994. Mean height growth and mortality figures are based on 1993 size classes.

Size classes (height in mm)	Absolute Frequency	Plants with Flowers	Mean height growth 1993–1994		Mortality
			Frequency	Growth	
1–10	100	0	102	0.86	26
11–20	51	0	50	0.54	2
21–30	29	0	47	2.49	4
31–40	21	3	17	5.41	0
41–50	17	4	16	7.63	0
51–60	17	10	20	7.7	1
61–70	15	7	9	3.67	0
71–80	20	14	17	2.38	1
81–90	11	10	13	-1.33	1
91–100	14	8	8	5.63	0
101–110	4	3	15	-0.83	3
111–120	5	3	5	7.8	0
121–130	9	9	9	5.38	1
131–140	5	4	6	0.33	0
141–150	7	6	2	6	0
151–160	3	3	4	0.5	0
161–170	3	3	5	13.25	1
171–180	1	1	0		
181–190	2	2	0		
191–200	0		1		
201–210	0		1	-42	0
211–220	0		0		
221–230	0		0		
231–240	0		0		

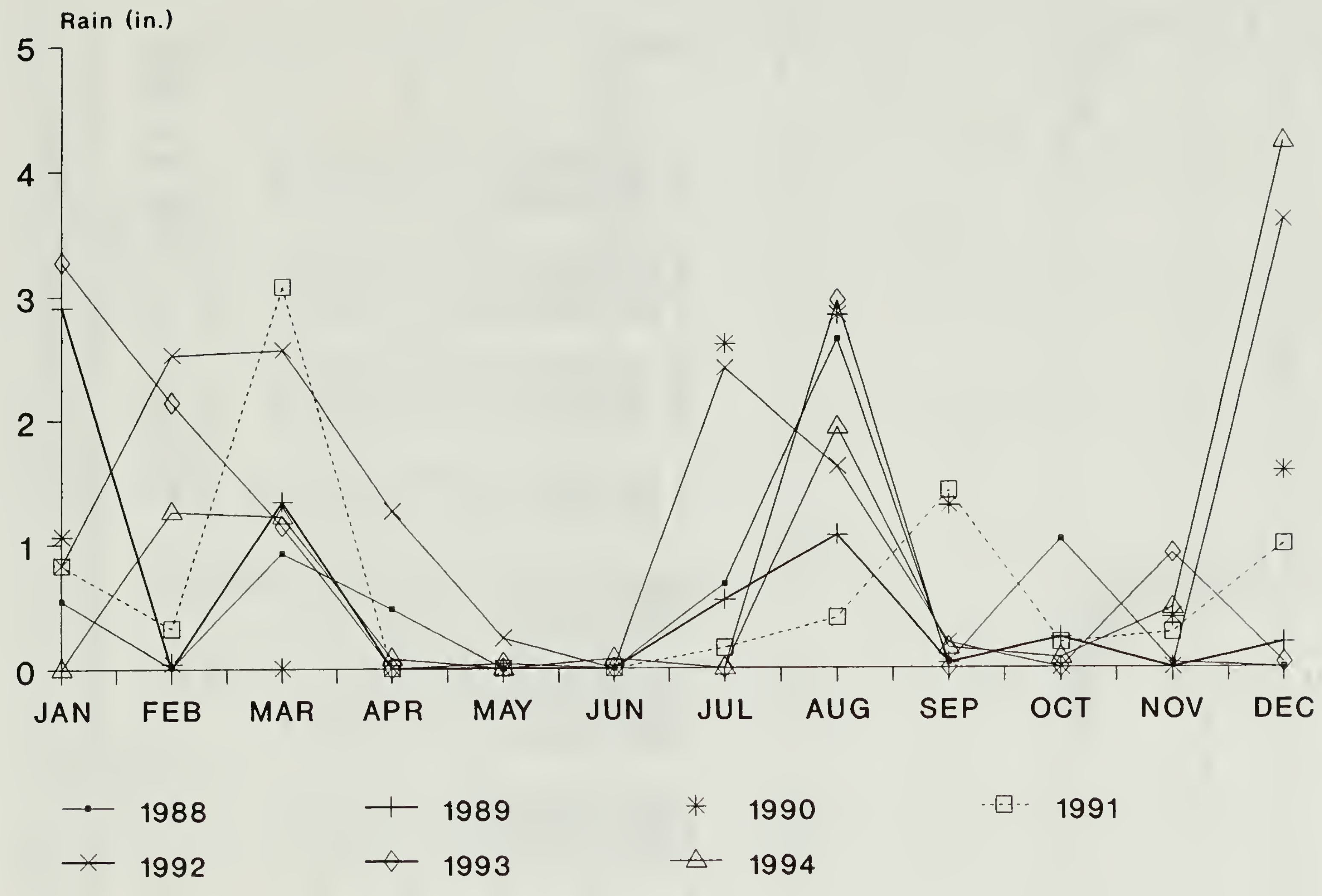


Figure 2. Rainfall data from automated weather station near acuña cactus *(Echinomastus erectocentrus* var. *acuñensis)* monitoring plots, Organ Pipe Cactus National Monument, Arizona, 1989–1994. January–April 1988 and July 1989 data were collected from Dripping Springs rain gauge.

Table 3. Comparison of acuña cactus (*Echinomastus erectocentrus* var. *acuñensis*) size distribution for all acuña monitoring plots in Organ Pipe Cactus National Monument, Arizona, 1988–1994.

Height (mm)	1988	1989	1990	1991	1992	1993	1994
1-30	114	168	181	281	249	198	180
31-60	58	49	65	54	47	53	55
61-90	35	39	39	38	43	38	46
91-120	28	30	25	34	37	28	23
121-150	10	11	11	25	24	17	21
151-180	2	3	2	9	13	9	7
181-210+	1	1	1	5	4	2	2
Total	248	301	324	446	417	345	334

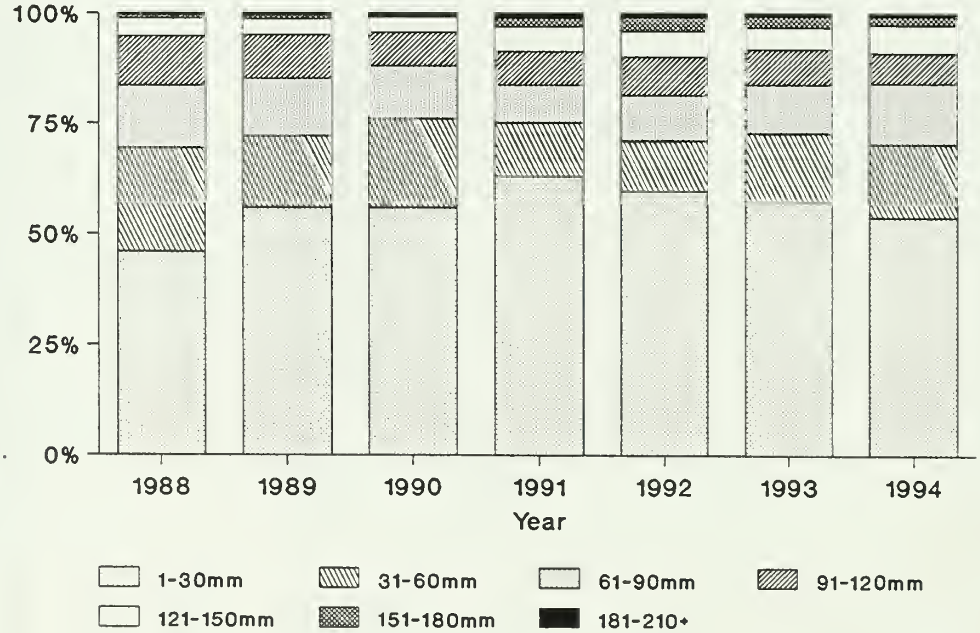


Figure 3. Size (height) distribution percentages of acuña cactus (*Echinomastus erectocentrus* var. *acuñensis*) plants in all acuña monitoring plots at Organ Pipe Cactus National Monument, Arizona, 1988–1994.

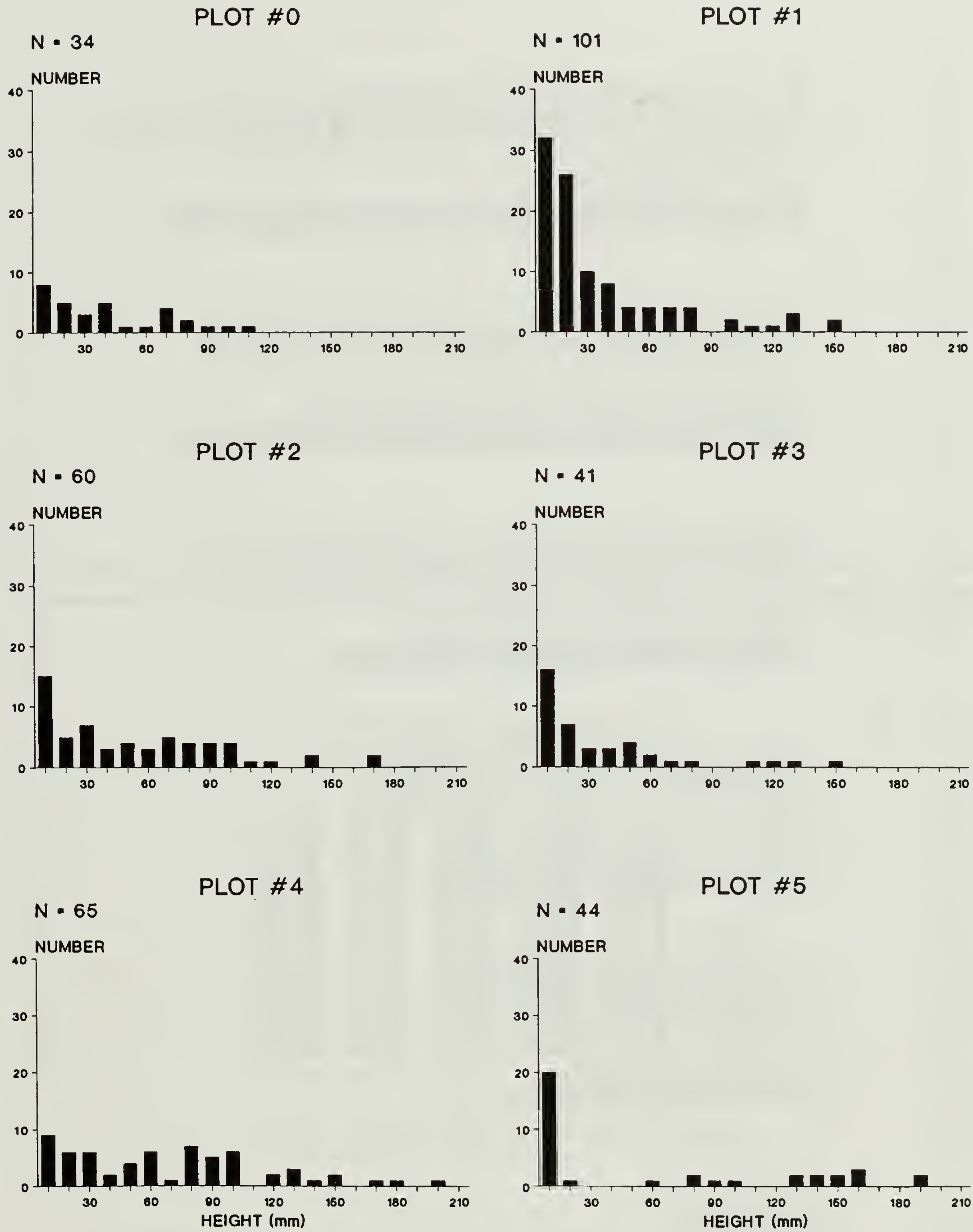


Figure 4. Size (height) distribution of acuña cactus *(Echinomastus erectocentrus* var. *acuñensis)* plants, by acuña monitoring plot, Organ Pipe Cactus National Monument, Arizona, 1994.

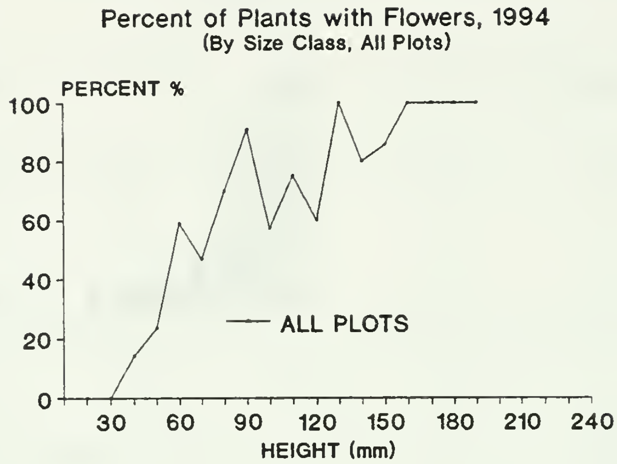


Figure 5. Percentage of acuña cactus *(Echinomastus erectocentrus* var. *acuñensis)* plants with flowers, by size class, for all acuña monitoring plots, Organ Pipe Cactus National Monument, Arizona, 1994.

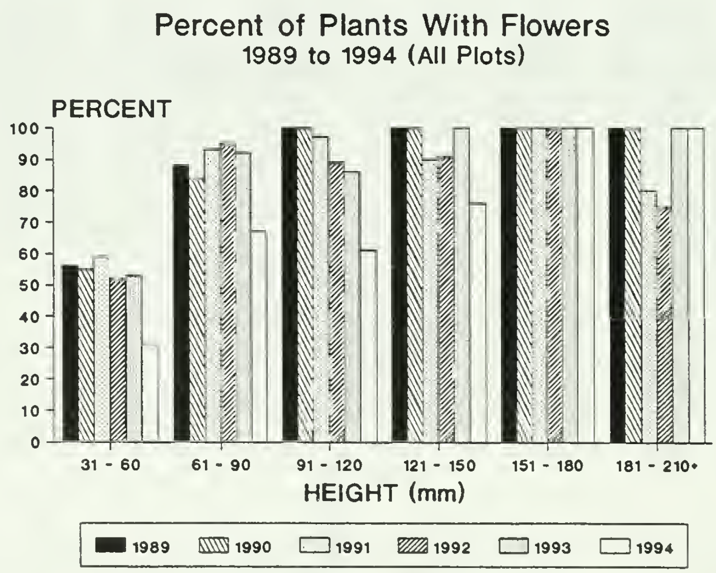


Figure 6. Percentage of acuña cactus *(Echinomastus erectocentrus* var. *acuñensis)* plants with flowers, for all acuña monitoring plots, Organ Pipe Cactus National Monument, Arizona, 1989–1994.

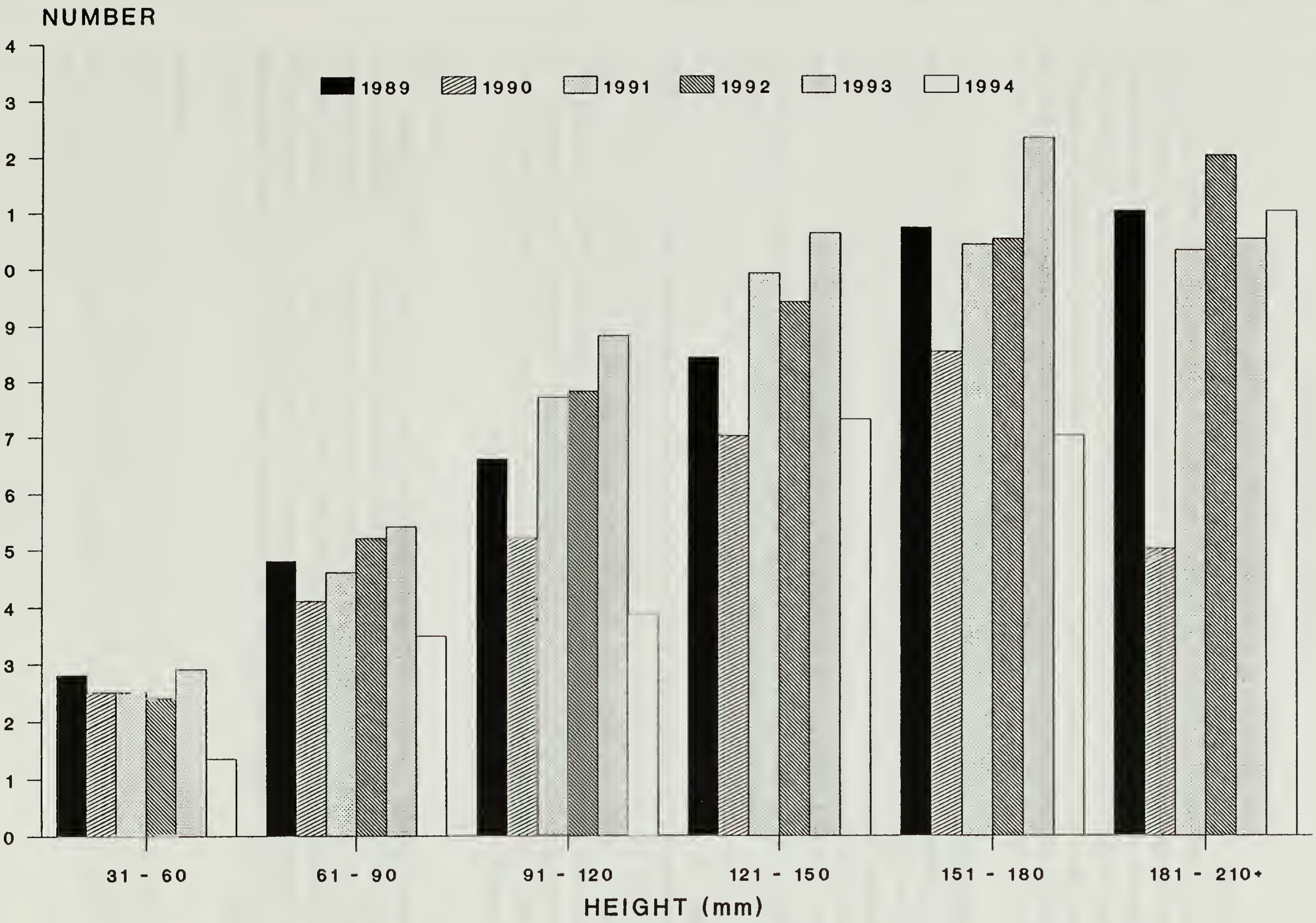


Figure 7. Average number of flowers on acuña cactus *(Echinomastus erectocentrus* var. *acuñensis)* plants, for all acuña monitoring plots, Organ Pipe Cactus National Monument, Arizona, 1989–1994.

Dahlia-rooted Cactus

Introduction

The dahlia-rooted cactus *(Peniocereus striatus)*, extremely cryptic (except when in flower or fruit), was chosen for monitoring in the Special Status Plants study due to its northern range limit in ORPI and the small size and vulnerability of its population in the monument. Only about 60 of these plants are known to exist at ORPI, and these are all concentrated on or next to 2 low, rocky hill areas on the south boundary. These 2 areas are immediately adjacent to agricultural fields that are subject to aerial spraying of pesticides and that are commonly occupied by livestock such as goats and cattle.

Project History

In 1990, 22 plants were located and tagged for future monitoring after a search of the principal habitat areas. Each plant was assigned a number and a metal tag placed on a short metal pin that was inserted in the ground near the plant.

Summary of 1994 Monitoring Activities

On 18 August 1994, all 22 plants were inspected. The time required to perform this monitoring is about a half day, including transportation.

Methods

Dalia-rooted cactus plants are inspected as to general health and condition during the summer rainy season when the reproductive status of plants can be determined. The number of new stems, if any, is recorded, along with the number of immature flower buds, mature flowers, and fruits. Also noted is any evidence of herbivory, or hedging. In addition, in 1994, the overall height of the plant was recorded, although this is not necessarily a reliable indicator of plant health. All of this information is entered into a Lotus spreadsheet for yearly comparisons, although much of the information is of a qualitative nature.

Results

The monitoring in 1994 was done "on time" in August, even though summer rains prior to monitoring had been sparse.There were fewer buds, flowers, and fruit than in 1994, no doubt due both to the timing of the monitoring and to relatively dry weather during the preceding year. Herbivory was much more in evidence, and this was extremely obvious on other vegetation (i.e., *Larrea tridentata*) in the area. This herbivory, plus a little die-back, resulted in generally lower numbers for overall height of the plants. All plants that looked dead in 1993 appeared to be dead still in 1994.

Desert Caper

Introduction

A population of desert caper *(Atamisquea emarginata)*, occurs in the Aguajita Wash area near Quitobaquito Springs. This population of approximately 100 individuals is the known northern limit of the species' range. The nearest population occurs 300 km south in west-central Sonora, Mexico. *Atamisquea emarginata* also occurs in Sinaloa and Baja California, Mexico, and in Argentina and Chile as well. Little is known about the ecology and natural history of the species. Flowers are pollinated by Lepidoptera, including *Ascia howarthii*, a butterfly species that requires *Atamisquea emarginata* as a host plant, and which in the United States occurs only in the Aguajita Wash area.

Although this population appears to be stable at the present time, it is considered to be the species that is most at risk for future declines or extinction within the monument because of its localized distribution, low population size, and large disjunction from other *Atamisquea. emarginata* populations. In addition, the population is at possible risk from human influences such as groundwater depletion and firewood collection. A long-term monitoring protocol was developed to examine the survival and condition of existing individuals.

Project History

In 1990, 30 individual plants from the Aguajita Wash population were tagged, measured and mapped on an acetate overlay of a color aerial photograph. Annual monitoring of these individuals entails locating the plants with the aerial photograph, measuring canopy and noting reproductive status. Data are entered into a spreadsheet.

Summary of 1994 Monitoring Activities

On 3 August, desert caper plants were monitored by personnel from the ORPI Resource Management Division. Reproductive condition was assessed and canopy and height were measured for each tagged plant.

Methods

All 30 tagged individuals of desert caper were located and monitored in the approximately 5-ha permanent study site. Plant size was calculated using 2 perpendicular measures of canopy diameter, roughly north-south and east-west, including all branches on the individual. Height was measured at the tallest portion of the plant. Plants with fruit and/or flowers were noted, and comments about overall condition were written as needed. Field data were then entered into a spreadsheet. Canopy coverage, in square meters, was estimated using the formula 0.25 * pi * diameter 1 * diameter 2.

Results

Figure 8 shows canopy coverage for each of the 30 plants since 1990. Although some plants showed a small decrease in canopy coverage, most plants increased in coverage or showed little change. At the time of monitoring, all but 2 plants bore fruit. There was no recent evidence of woodcutting in the area.

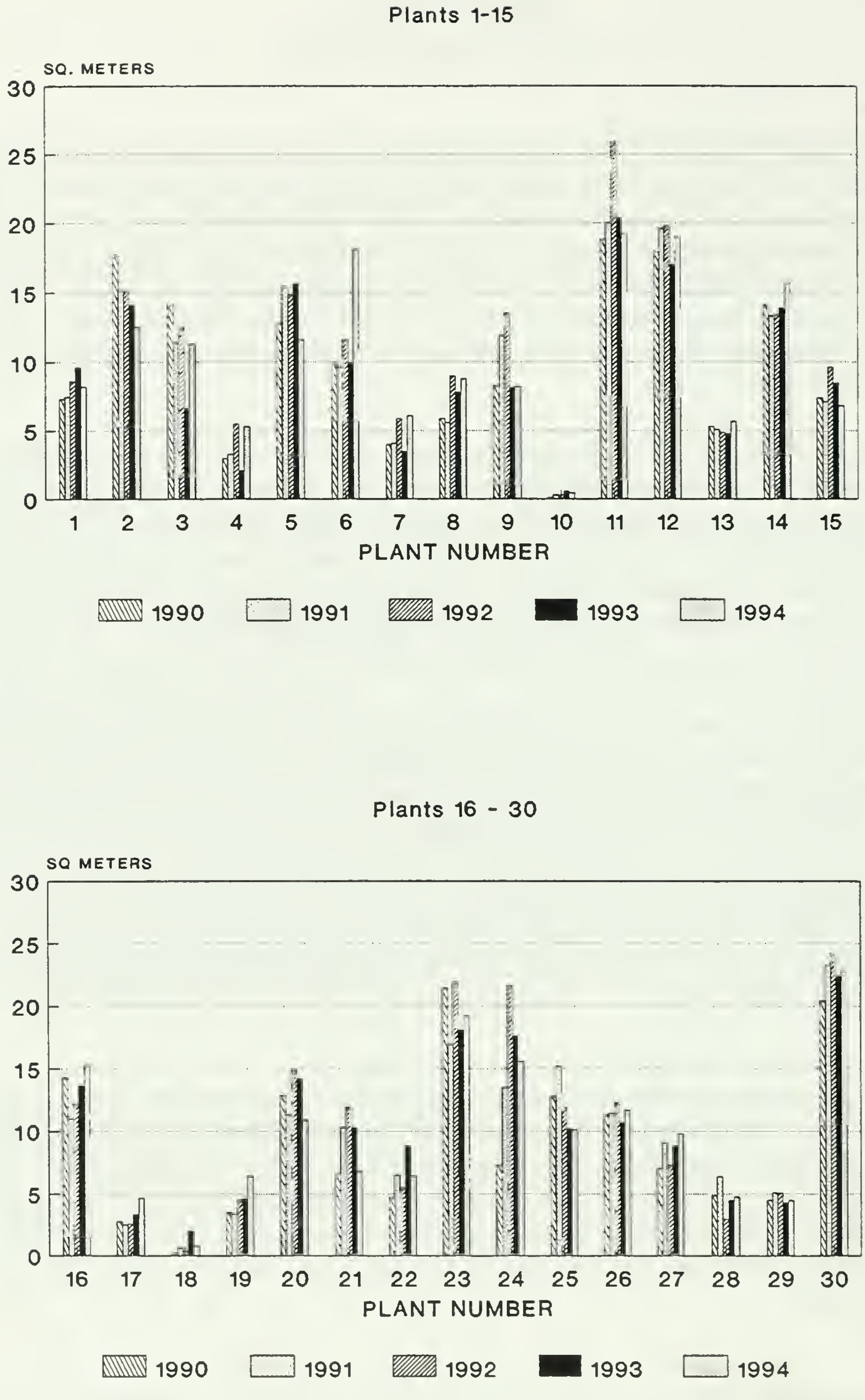


Figure 8. Canopy cover of the 30 desert caper (*Atamisquea emarginata)* plants monitored at Organ Pipe Cactus National Monument, Arizona, 1990–1994.

Organ Pipe Cactus and Senita Cactus

Introduction

Organ pipe cactus *(Stenocereus thurberi)*, is a columnar cactus species that occurs throughout the monument primarily on south- to southeast-facing rocky slopes. Senita cactus *(Lophocereus schottii)*, also columnar, occurs only along the southernmost boundary of the monument, especially in relatively moist habitats along wash banks composed of coarse sediments (Parker 1988). Although they occur extensively throughout northwestern Mexico and Baja California, both cactus species are near their northern range limit in the monument.

Since 1970, annual growth measurements have been taken from tagged individuals of both species located on study plots in the central and southern Puerto Blanco Mountains of the monument. In 1990, as a part of the SEP project titled Special Status Plants, additional plots were set up to monitor the growth of these species.

Human-influenced impacts or threats to either organ pipe cactus or senita cactus populations within the monument, though not presently obvious, might occur from pesticide drift from Mexican agriculture, past grazing, and possibly from global climate change.

Project History

In 1970, park ranger Fred Goodsell selected for long-term growth monitoring 3 organ pipe cactus plants from a population growing on a steep south- to southeast-facing rocky slope in the central Puerto Blanco Mountains, and 9 senita cactus plants growing along a wash on a basin floor in the southern Puerto Blanco Mountains. These individuals represented a wide range of sizes but were sufficiently small to allow access for stem measurements.

Annual growth measurements have been made on these individuals by monument staff since 1970. A total of 30 organ pipe cacti and 2 senita cacti have been monitored the entire 24-year period. Some cacti are no longer monitored due to mortality or severely reduced vigor.

In 1990, as a part of the Special Status Plants project, additional plots were set up for the purpose of assessing intersite variability in growth rates. A plot of 20 organ pipe cactus individuals was established in the Bates Mountains and a plot with an additional organ pipe cactus and 3 senita cactus plants located in the small hills rising out of the alluvial flats on the south park boundary. In addition, 4 more senita cacti were selected for monitoring on the original southern Puerto Blanco Mountains plot.

1994 Monitoring Activities

During the first 2 weeks of January, stem measurements were made on organ pipe cacti and senita cacti.This monitoring was conducted by park resource management staff, following the protocols in "Special-status Plants Monitoring Protocol" (Ruffner Associates 1995).

Methods

Each stem of every study plant has been tagged and labelled. As individual stems grow in length and become more curved, a wooden dowel is inserted 1–2 cm into the tissue between the stem tip and stem base to allow for measurement precision. Measurement of stem tip-peg distances has been repeated annually since 1970 for the original plots, and since 1990 for the new plots. Distances are measured to the nearest 0.25 in. with a steel tape measure.

Results

Using the 1970–1983 datasets for both cactus species, Parker (1988) developed mathematical models that related plant growth rates to plant size, age, and meteorological conditions with analysis of variance and regression analysis. For this report, the complete dataset (1970–1993) for organ pipe cactus only, was tested on the size-growth models relating *annual plant growth* to both *plant size* and *stem number,* with least-squares nonlinear regression analysis, and *mean plant growth* to *winter precipitation* and *freeze frequency,* with multivariate regression analysis.

The variables used in the original analysis included:

Dependent variables:

Annual stem growth	... $(\text{stem lgth})_t - (\text{stem lgth})_{t-1}$
Annual plant growth	... $\sum_{i=1}^{n} (\text{annual stem growth})_i$
Mean plant growth	...$(\sum_{j=1}^{p} [\text{annual plant growth}]_j)/p$

Independent variables:

Plant size	$\sum_{i=1}^{n} (\text{stem length})_i$
Stem number	... Number of stems

Meteorological factors:

Freeze frequency	... No. days November_{t-1} - April_t with minimum temperature $\leq$ 0 C.
Summer precip.	... Precipitation for June_t - September_t
Winter precip.	... Precipitation for November_{t-1} - April_t

t = year; i = the ith stem; n = the number of stems on a plant; j = the jth plant; p = the number of plants in the sample.

Annual plant growth for each plant in each year 1970–1993 constituted the observational unit (N).

In non-linear regression models derived from the 1970–1983 dataset, Parker (1988) found that annual plant growth (Y) was significantly related to both plant size and stem number (X). Coefficient of determination values (R^2) were 0.83 and 0.86, respectively. Mean growth rates ± 1 standard deviation were found to be 0.07 ± 0.06 m/yr for plants <1 m (3 ft) tall, and 0.62 ± 0.30 m/yr for those >5 m (16 ft) tall. Although the current dataset (1970–1993) had comparable growth rates of 0.05 ± 0.05 m/yr and 0.59 ± 0.34 m/yr for the above size classes, these data did not fit as well when tested on the regression models (Figs. 9 and 10). Though still greater than 50% of the variability of annual plant growth can be explained by plant size and stem number, it is possible these particular growth models do not accurately predict senescense.

The 1990–1993 dataset from the central Puerto Blanco Mountains (Baker Mine plot) was separated and compared with same years data from the recently established Bates Mountains plot in an attempt to begin exploring intersite variability in growth rates. Growth rates on the Baker Mine plot were 0.07 ± 0.03 m/yr for plants <1 m (3 ft) tall, and 0.65 ± 0.38 for those >5 m (16 ft) tall. Growth rates of plants on the Bates Mountains plot were somewhat higher at 0.09 ± 0.05 m/yr and 0.81 ± 0.31 m/yr for the above size classes (Table 4). Original non-linear regression models and linear regression models were applied to both datasets (Figs. 11 and 12).

Multivariate regression models relating mean plant growth to winter precipitation and freeze frequency were applied to the Baker Mine dataset, 1970–1993 (Fig. 13). Though confirming the findings of Parker (1988) that mean plant growth values in organ pipe cacti were high following unusually wet and mild winters, a larger proportion of the mean plant growth remained unexplained ($R^2 = 0.59$ 1970–1993 versus $R^2 = 0.87$, 1970–1983). Meteorological data from the official weather station at monument headquarters were used for the analysis.

Table 4. Mean annual growth of organ pipe cactus *(Stenocereus thurberi)* by plot, time period, and plant size class at Organ Pipe Cactus National Monument, Arizona.

	Baker Mine		Bates Mountains
Plant Size Class	1970–1993	1990–1993	1990–1993
< 1 m	0.05 ± 0.05 (108)	0.07 ± 0.03 (5)	0.09 ± 0.05 (21)
1–5 m	0.22 ± 0.14 (236)	0.25 ± 0.15 (25)	0.22 ± 0.17 (30)
> 5 m	0.59 ± 0.34 (372)	0.65 ± 0.38 (89)	0.81 ± 0.31 (26)

Note: Numbers are mean ± 1 standard deviation in meters, with the number of plants in each size class in parentheses. Observe that by the 1990–1993 analysis period for the Baker Mine plot, most plants had grown into the > 5 m size class.

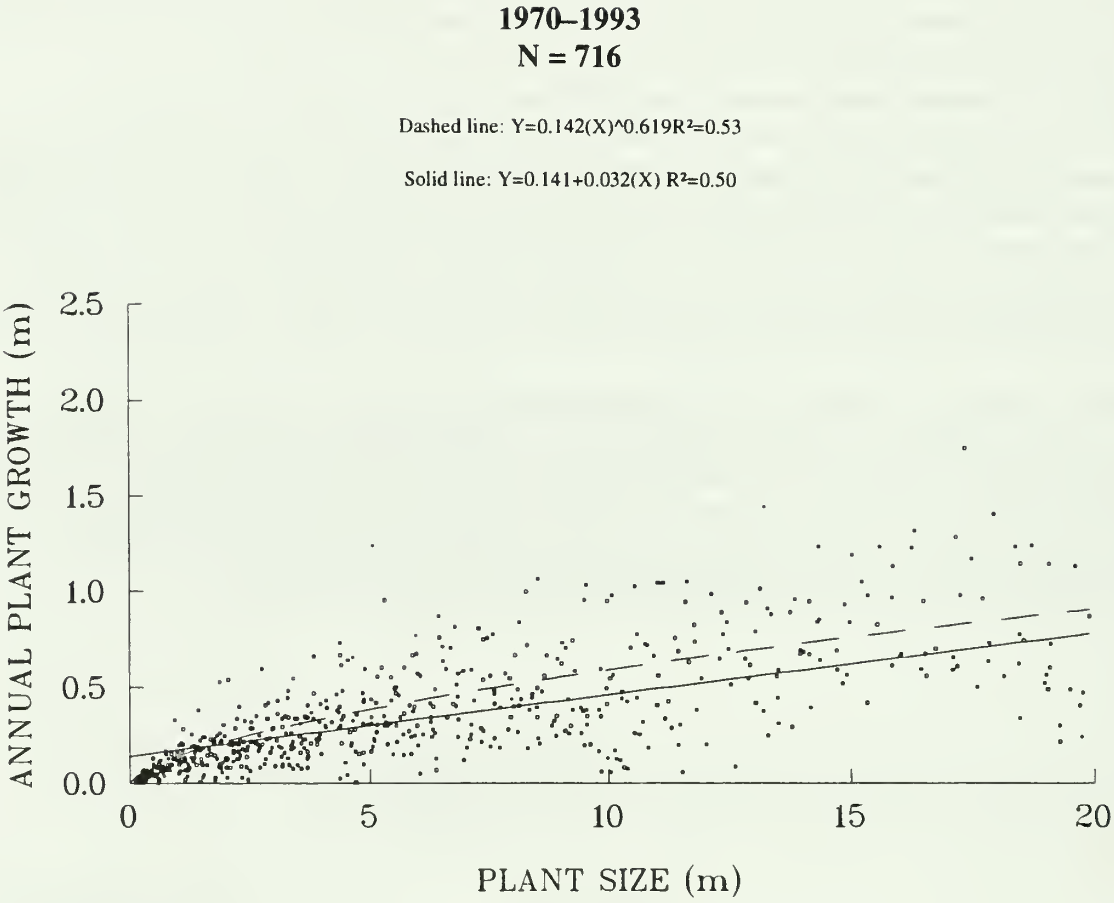


Figure 9. Relationship of annual plant growth (Y) to plant size (X) for organ pipe cactus *(Stenocereus thurberi)* on the Baker Mine Plot, Organ Pipe Cactus National Monument, Arizona, 1970–1993. The dashed line is the original non-linear regression model that Parker (1988) applied to the 1970–1983 dataset. The solid line is a linear regression model.

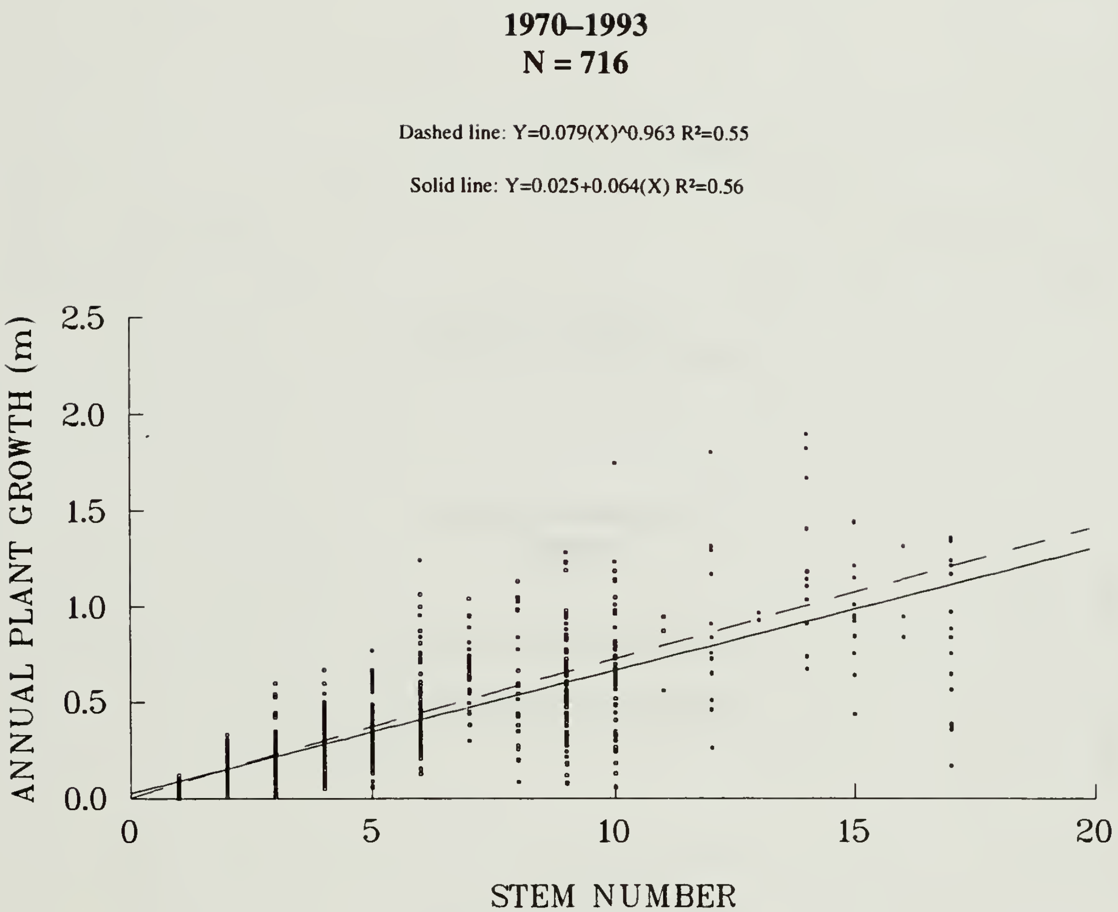
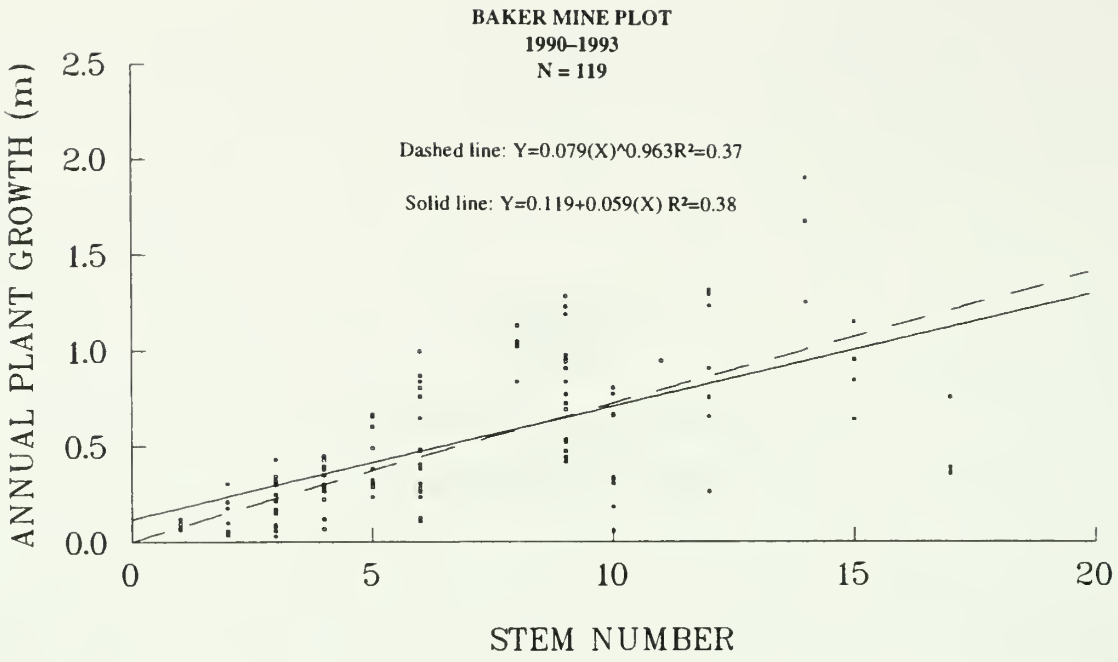


Figure 10. Relationship of annual plant growth (Y) to stem number (X) for organ pipe cacti *(Stenocereus thurberi)* on the Baker Mine Plot, Organ Pipe Cactus National Monument, Arizona, 1970–1993.



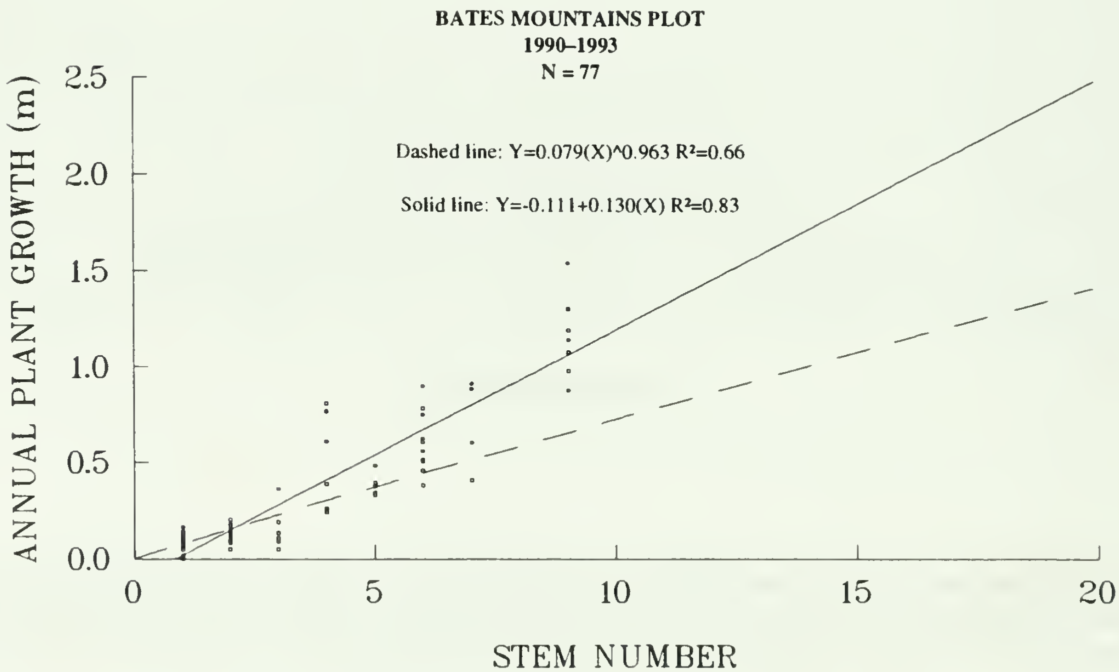
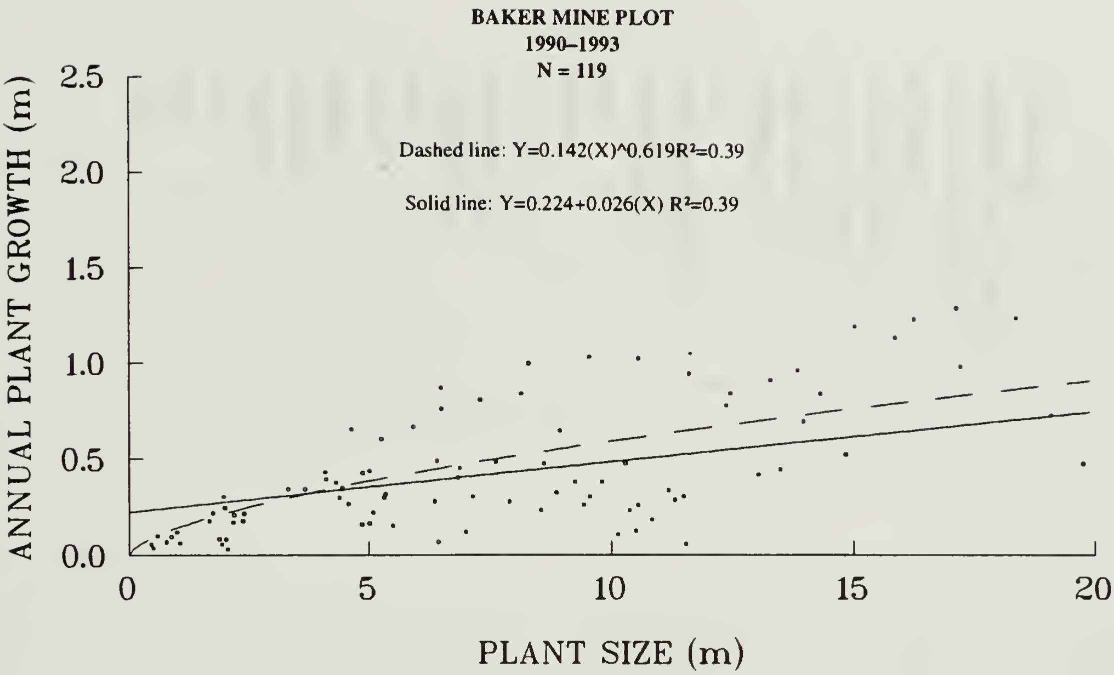


Figure 11. Relationship of annual plant growth (Y) to stem number (X) for organ pipe cacti *(Stenocereus thurberi)* on 2 plots, Organ Pipe Cactus National Monument, Arizona, 1990–1993. The dashed line is the original non-linear regression model that Parker (1988) applied to the 1970–1983 dataset. The solid line is a linear regression model.



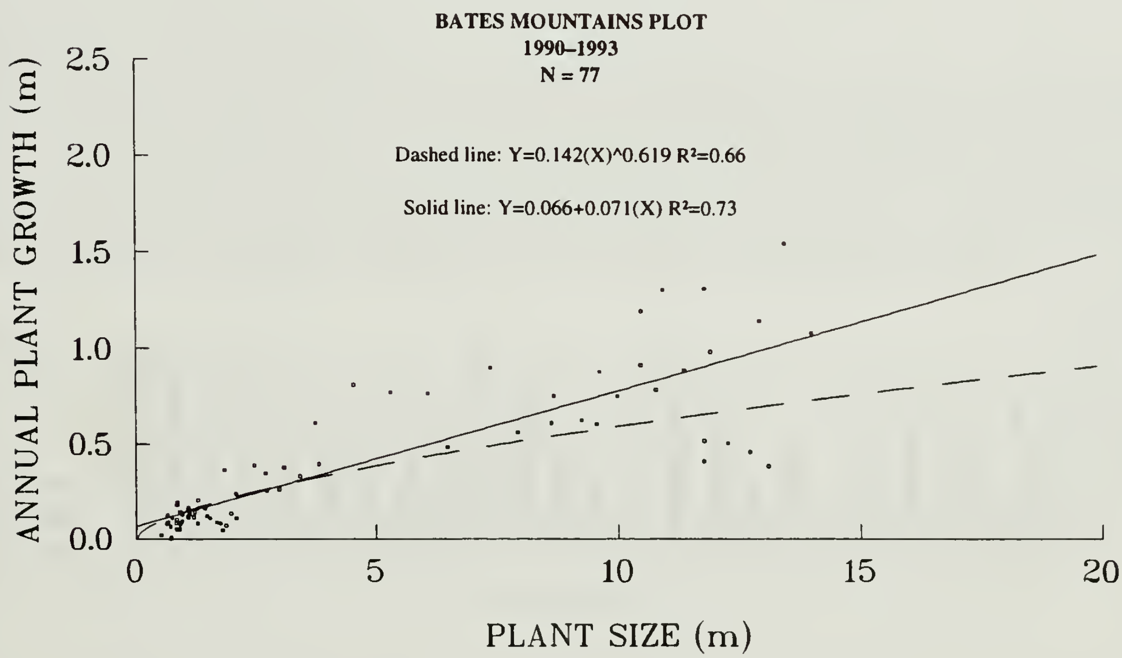


Figure 12. Relationship of annual plant growth (Y) to plant size (X) for organ pipe cacti *(Stenocereus thurberi)* on 2 plots, Organ Pipe Cactus National Monument, Arizona, 1990–1993. The dashed line is the original non-linear regression model that Parker (1988) applied to the 1970–1983 dataset. The solid line is a linear regression model.

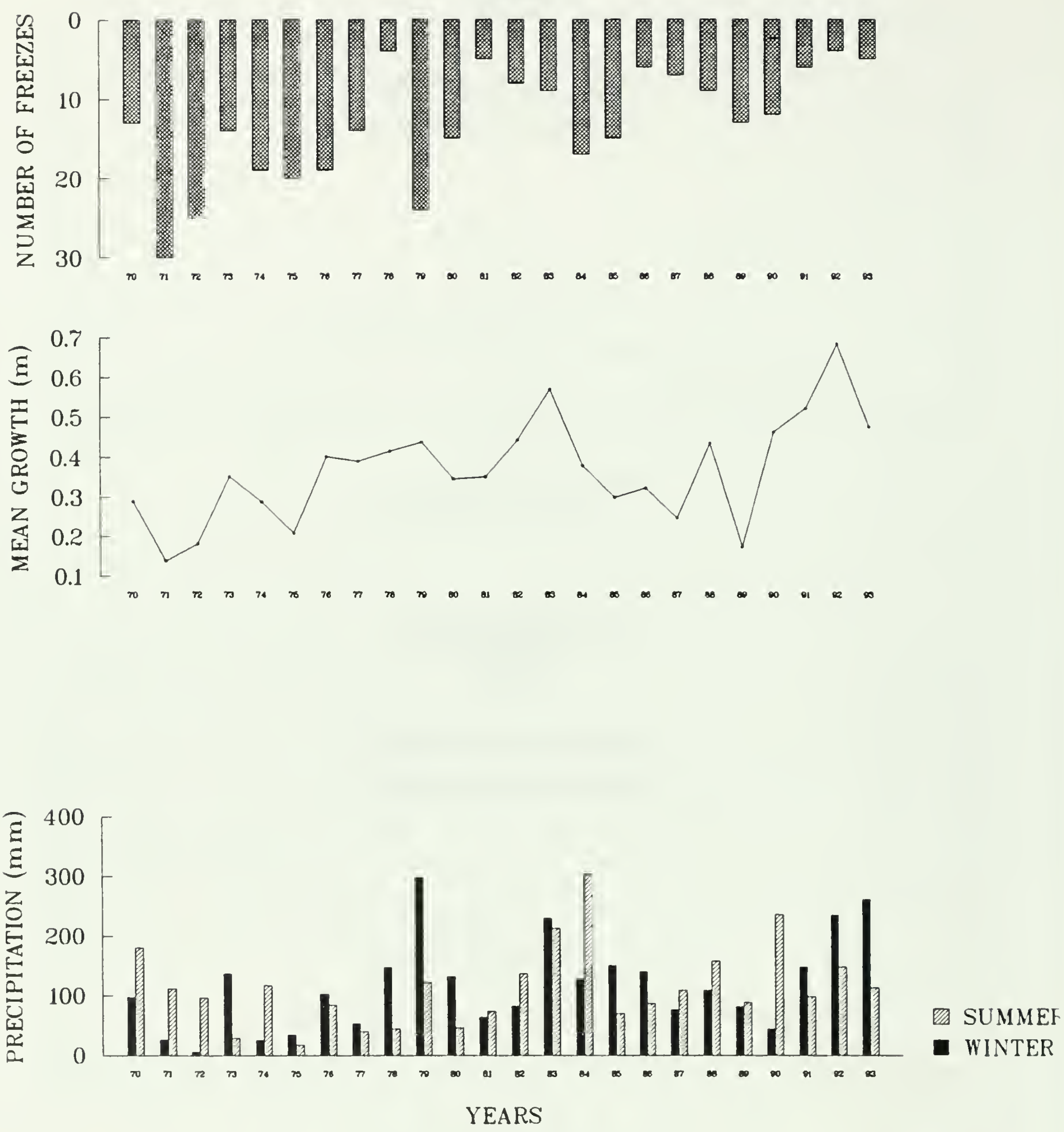


Figure 13. Relationship of mean plant growth to freeze frequency and winter precipitation for organ pipe cacti *(Stenocereus thurberi)* on the Baker Mine Plot, Organ Pipe Cactus National Monument, Arizona, 1970–1993. Model: mean plant growth (Y) = 14.035 + 0.035 (winter precip.[X_1]) - 0.284 (no. of freezes[X_2]). R^2=0.59. Note: freeze data for 1970–1975 were obtained from Parker (1988).

Lizards

Introduction

The objective of the lizard monitoring protocol is to measure population size and dynamics in lizards, which may be correlated with natural and human-caused environmental changes at ORPI (Rosen and Lowe 1995). Additionally, the lizards and the findings for them as ectothermic vertebrates have intrinsic biological importance. They form one component within the broader EMP that is planned to be capable of detecting biotic effects of global climate change, of local human-caused disturbance and of natural environmental fluctuation. We should be able to document the effects of environmental fluctuations on lizards and use this information to predict and/or illustrate the consequences of human-caused environmental change at ORPI (Rosen and Lowe 1995).

Project History

Beginning with the end of the initial 4-year (1987–1991) survey of ORPI herpetofauna, monument staff began implementation of the monitoring protocol, consisting of twice-yearly (spring and summer) walking of standardized lizard transects. In the beginning, only the Core I sites were visited, due to constraints of time and personnel, but by 1993 all sites were visited during both activity seasons.

Summary of 1994 Activitites

From 1 May to 12 June and again from 18 August to 12 September, lizards were monitored. The project was carried out by personnel from the Division of Resources Management and Research on all 13 of the EMP study sites for which lizard transects had been established, as well as 2 additional sites utilized only for lizard monitoring. Data for peak numbers of lizards observed per walk are compared here with similar data for the previous 4 years, and data on distances from transect midlines are presented graphically for future reference regarding technique.

Methods

Lizards are monitored using a line transect methodology, whereby a transect, varying in length from 100 to 300 m, is walked repeatedly; all lizards seen within 7.5 m on either side of the center line are recorded. The following data were taken: (1) distance from transect origin, (2) distance from center line, (3) species, (4) size/age class, and (5) time. Gender is recorded if it can be determined. Air and ground temperatures are recorded, and relevent notes are optionally added. Eight sites have just 1 line, while 6 sites have 2 lines each, walked alternately on a single day. The Pozo Nuevo EMP site has 4 lines, which require 2 people or 2 days to complete.

Each line is walked beginning at the east end so lizards can be easily seen basking in the morning sun, and all lines are walked beginning with first warmth, shortly after sunrise. A clear, warm, and fairly calm morning is required for high lizard activity. The walks are timed to coincide with the peaks of activity of each of the various species of lizards present, with particular attention being given to the "indicator species," usually whiptail lizards *(Cnemidophorus* spp.*)*, around

which the timing and duration of each session are generally determined. This is accomplished partially by continuously monitoring activity in the area away from the transects by, in general, evenly spacing transits down the transect at intervals of 20–40 minutes, as indicated by lizard activity levels. Once the number of individuals of the indicator species observed has peaked and is diminishing for 1 or 2 more walks, the session is ended. Each line is run once in the late spring and once again in mid-summer, after the onset of the summer rains. The design of the protocol is such that 1 person can walk 2 lines alternately, since one would not want to walk a line so frequently as to frighten the lizards off the line. The methods used follow the monitoring protocols set forth in Rosen and Lowe (1995).

Results

Unlike some other animal populations, such as insects or rodents, lizard populations are not tied directly to recent rainfall and vegetative abundance. Although these factors may be the ultimate causes, other factors, such as temperature, humidity, soil moisture, and the populations of reproducing adult lizards and of predators, may have a very significant influence that can modify and delay effects of rainfall and the resulting growth of vegetation. Thus, some of the results that are seen are not necessarily easily explained in terms of recent weather. Another important factor is the timing of the monitoring days in terms of reproductive activity (for which the seasonal timing of the monitoring is designed) and the effects on lizard activity of the weather of the day and of the preceding week. This is especially noticeable in the spring when mornings can be quite cool, and in the summer when there can be effects of the monsoons such as clouds on the eastern horizon or a damp soil surface.

The year 1994 began very differently from the previous 2 years in that winter rains were sparse and there was only a slight production of spring annuals. The previous summer had been relatively dry as well, so the herbaceous ground cover consisted mainly of the remains of the previous spring, with little or no fresh new growth. Significant herbivory of creosotebush *(Larrea tridentata)* was noted at many sites, with pieces of stems and leaves littering the ground around virtually every plant. Numbers for most species were consistently down from the previous year.

The same paucity of rainfall also characterized the summer of 1994, with a late August start to a brief monsoon season, and a resulting poor yield of summer annuals. Ground cover still consisted of an extremely thinned out association of spring annuals from 1993, these being principally *Sisymbrium* spp., *Amsinckia* spp. and *Cryptantha* spp. There was a period of rain at the beginning of September, but many sites seemed to have missed significant precipitation, with a result of a complete absence of green vegetation. Still, lizards were observed. Some sites, especially those that received a good portion of rain in August, yielded high numbers of western whiptail *(Cnemidophorus tigris)*. Numbers were somewhat low for sideblotched lizard *(Uta stansburiana)* and lower still for zebra-tailed lizard *(Callisaurus draconoides)*, an indicator species at a few sites. Tree lizard (*Urosaurus ornatus)* was also seen in greatly reduced numbers, even in good bosque or wash bank habitat.

For reasons that still defy explanation, Alamo Canyon continued to yield remarkably few lizards, even though vegetative conditions there were quite good and the weather was entirely appropriate for monitoring. The transect was run once in the spring, with a yield of 2 tree lizards and 1 canyon spotted whiptail *(Cnemidophorus burti)*. Three times the transect was run in the summer, with a total of 1 tree lizard and 2 Sonoran whipsnakes *(Masticophis bilineatus)*, one of which was quite large. Predators such as snakes and roadrunners *(Geococcyx californianus)* are a common sight in Alamo Canyon, but it would seem that other factors must also be at work. Results on the transects at Aguajita improved somewhat over 1993 but were still disappointing, especially for tree lizards.

Other interesting results are worth mention. There were continued high numbers in summer of western whiptails at Armenta Ranch (an open mesquite habitat that is fringed by stands of creosotebush), even though the site showed a complete absence of summer annuals. The Lower Colorado Larrea site, which was likewise parched, also had many western whiptails, but not one longtailed brush lizard *(Urosaurus graciosus)* was seen. Roadrunners were seen or heard at many sites, more than the usual. A Gila monster *(Heloderma suspectum)* was encountered on the transect in Alamo Canyon in the spring and at the beginning of the bosque transect at Aguajita Wash in the summer. A pair of common collared lizards *(Crotaphytus collaris)* was seen perched on large rocks on the hill transect at Pozo Nuevo. A Mojave rattlesnake *(Crotalus scutulatus)* lay coiled peacefully right on the transect center line at Burn site, although it was not observed until the second walk along the transect. Dos Lomitas continued to be the most consistently productive of all the sites, with large peaks for the wesern whiptails on both of the 100-m transects. With a warm and very wet winter of 1994–95, it will be quite interesting to see whether lizard populations rebound in 1995.

Observed distances from lizard transect midlines are summarized in Figure 14, and age class distribution is presented in Figure 15. Peak lizard data for each site are summarized in Figures 16–39.

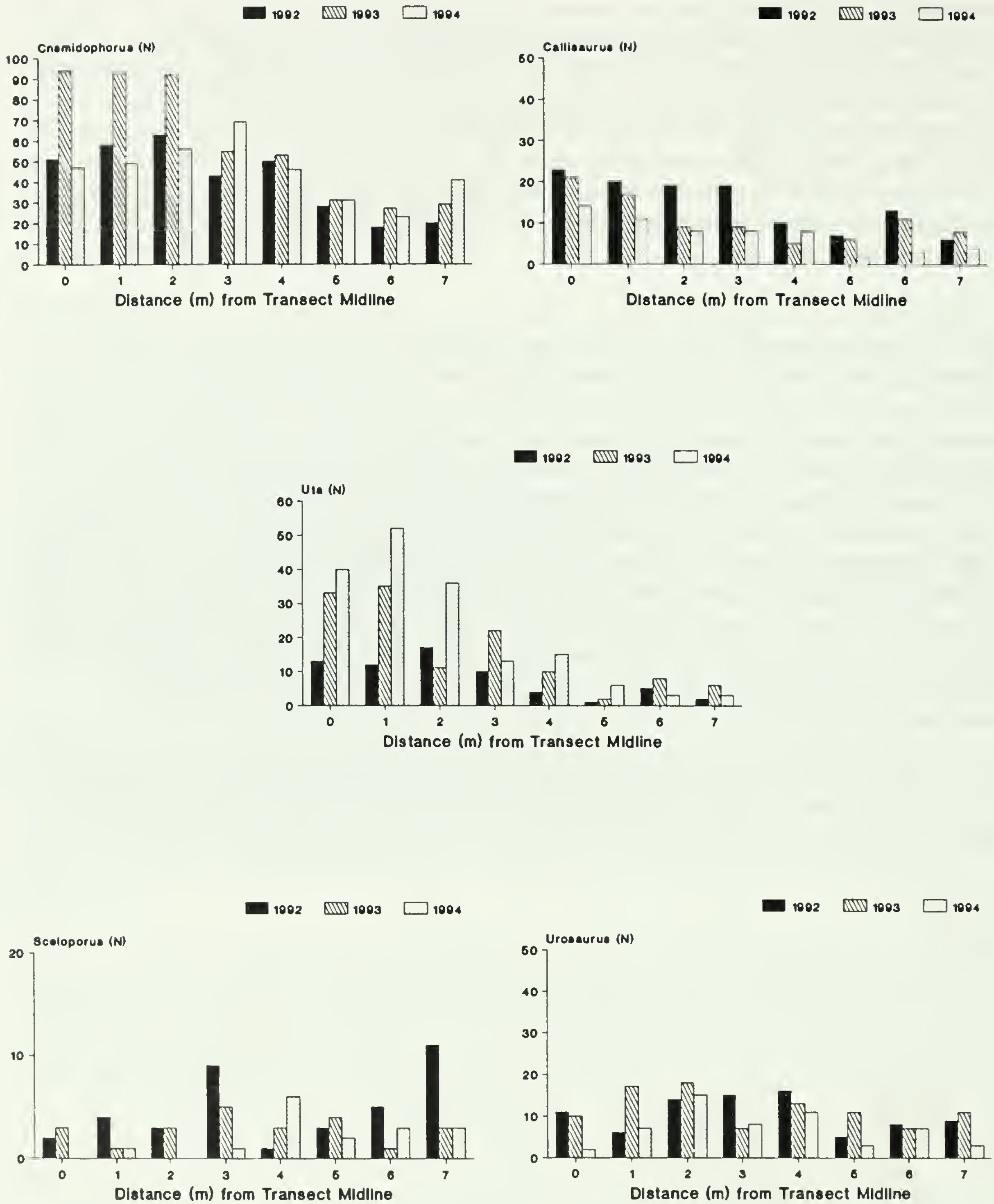
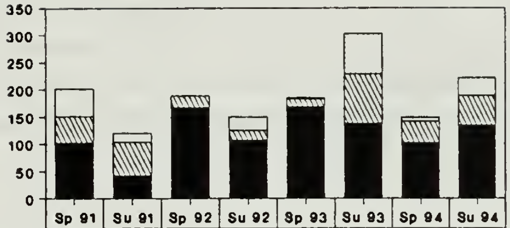


Figure 14. Observed distances from lizard transect midlines, Organ Pipe Cactus National Monument, Arizona, 1992–1994.

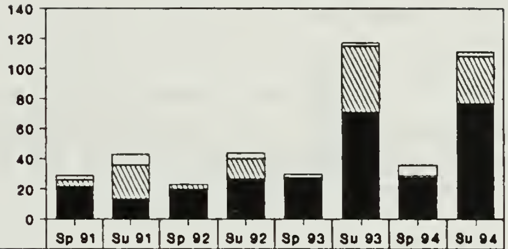
Cnemidophorus tigris
(and C. burti)



	Sp 91	Su 91	Sp 92	Su 92	Sp 93	Su 93	Sp 94	Su 94
Juveniles	50	16	0	25	2	74	7	32
Subadults	48	61	21	18	14	91	38	54
Adults	103	43	167	107	169	138	103	135

Adults Subadults Juveniles

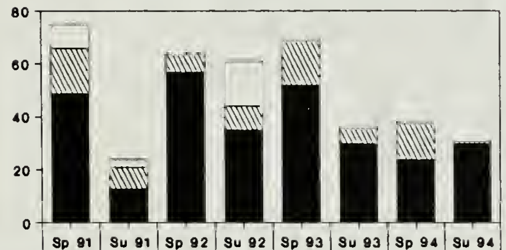
Uta stansburiana



	Sp 91	Su 91	Sp 92	Su 92	Sp 93	Su 93	Sp 94	Su 94
Juveniles	3	7	0	4	2	2	7	3
Subadults	4	22	3	13	0	44	1	31
Adults	22	14	20	27	28	71	28	77

Adults Subadults Juveniles

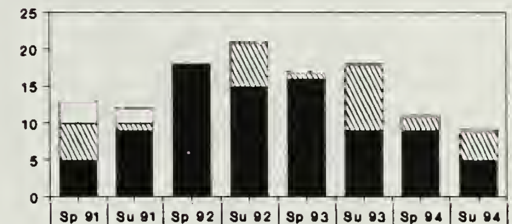
Callisaurus draconoides



	Sp 91	Su 91	Sp 92	Su 92	Sp 93	Su 93	Sp 94	Su 94
Juveniles	9	3	0	17	0	0	0	0
Subadults	17	8	7	9	17	6	14	1
Adults	49	13	57	35	52	30	24	30

Adults Subadults Juveniles

Sceloporus magister
(and S. clarki)

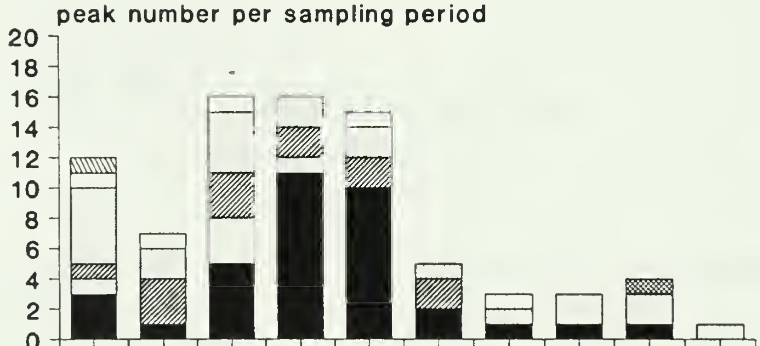


	Sp 91	Su 91	Sp 92	Su 92	Sp 93	Su 93	Sp 94	Su 94
Juveniles	3	2	0	0	0	0	0	0
Subadults	5	1	0	6	1	9	2	4
Adults	5	9	18	15	16	9	9	5

Adults Subadults Juveniles

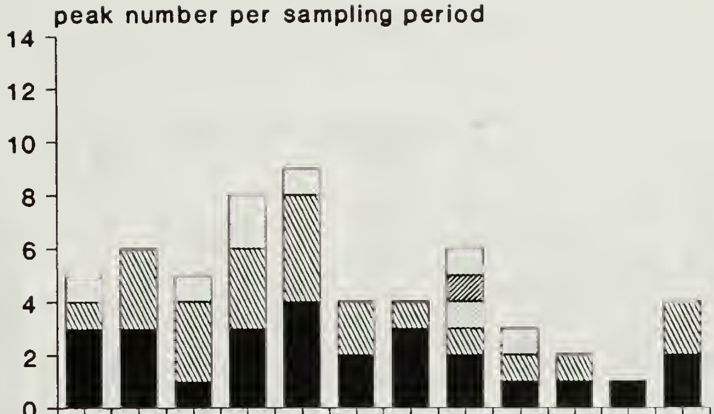
Figure 15. Age structure of lizards monitored, Organ Pipe Cactus National Monument, Arizona, 1991–1994.

Note: Figures 16–39 chart peak values for lizard species observed per transect. The following species abbreviations and taxons are used within charts: **Callisaurus** = zebra-tailed lizard (*Callisaurus draconoides);* **Cnemi burti** = canyon spotted whiptail (*Cnemidophorus burti*); **Cnemidophorus, Cnemi tigris** and **Cnemidophorus tigris** = western whiptail; **Crotaphytus** and **Crotaphytus collaris** = common collared-lizard; **Dipsosaurus** = desert iguana (*Dipsosaurus dorsalis*), **Gambelia** = longnosed leopard lizard (*Gambelia wislizeni*); **Heloderma** = Gila monster (*Heloderma suspectum*); **Phrynosoma solare** = regal horned lizard; **Sceloporus** = desert spiny lizard (*Sceloporus magister*) for all sites except Alamo Canyon (Figure 16), in which case the species is Clark spiny lizard (*Sceloporus clarki*); **Urosaurus** and **Urosaurus ornatus** = tree lizard, except where specified as **Urosaurus graciosus** (longtailed brush lizard); **Uta** and **Uta stansburiana** = sideblotched lizard.



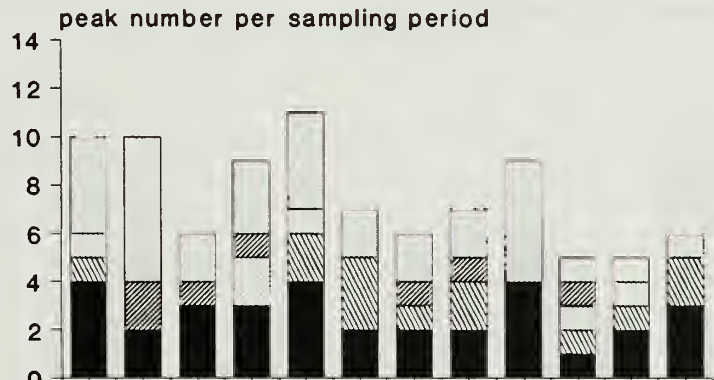
	8-89	5-90	5-91	8-91	5-92	8-92	4-93	8-93	5-94	9-94
Heloderma									1	
Cnemi tigris	1									
Crotaphytus	1	1	1		1		1			
Urosaurus	5	2	4	2	2	1	1	2	2	1
Sceloporus	1	3	3	2	2	2				
Callisaurus	1		3	1						
Cnemi burti	3	1	5	11	10	2	1	1	1	

Figure 16. Peak values for lizard species, Alamo Canyon, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



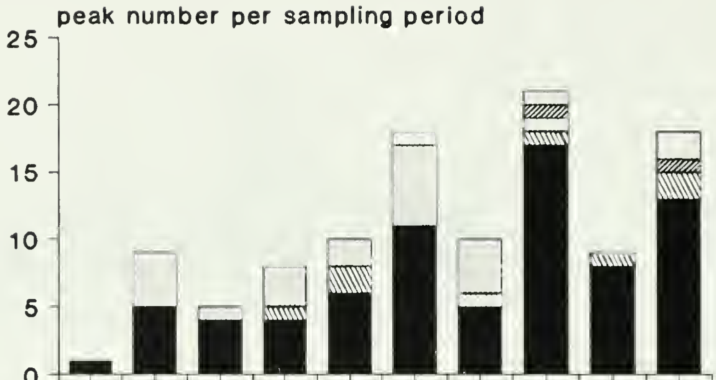
	4-89	8-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	8-94
Urosaurus								1	1			
Sceloporus								1				
Callisaurus	1		1	2	1			1				
Uta	1	3	3	3	4	2	1	1	1	1		2
Cnemidophorus	3	3	1	3	4	2	3	2	1	1	1	2

Figure 17. Peak values for lizard species, Aguajita #1 (Saltbush) 100-m transect, Organ Pipe Cactus National Monument, 1989–1994.



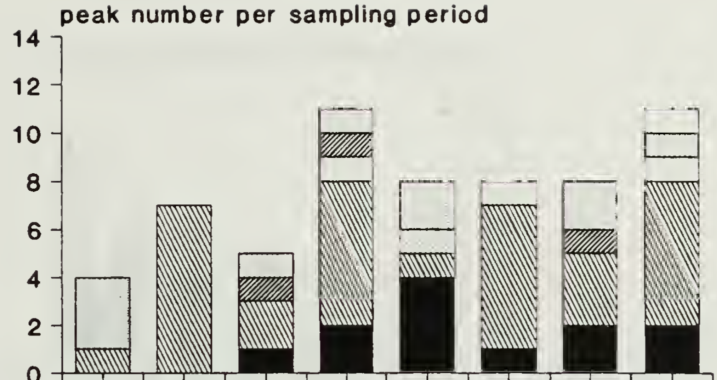
	4-89	8-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	8-94
Heloderma											1	
Urosaurus	4	6	2	3	4	2	2	2	5	1	1	
Sceloporus		2	1	1			1	1		1		
Callisaurus	1			2	1					1		1
Uta	1				2	3	1	2		1	1	2
Cnemidophorus	4	2	3	3	4	2	2	2	4	1	2	3

Figure 18. Peak values for lizard species, Aguajita #2 (Bosque) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



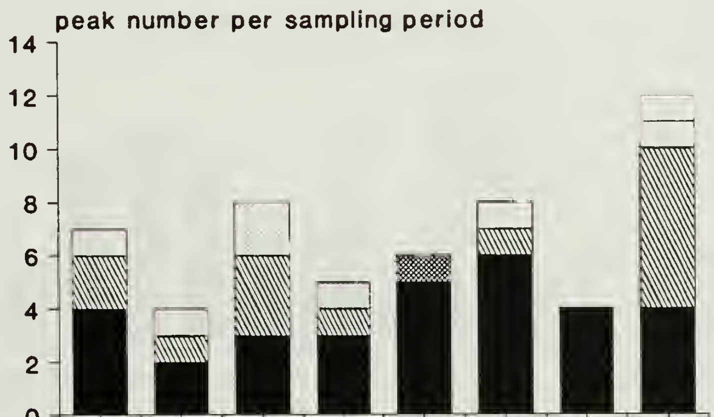
	9-88	4-89	7-89	5-90	8-90	5-91	5-93	9-93	5-94	9-94
Dipsosaurus						1				
Urosaurus		4	1	3	2	6	4	1		2
Sceloporus								1		1
Callisaurus							1	1		
Uta				1	2			1	1	2
Cnemidophorus	1	5	4	4	6	11	5	17	8	13

Figure 19. Peak values for lizard species, Armenta Ranch 200-m transect, Organ Pipe Cactus National Monument, Arizona, 1988–1994.



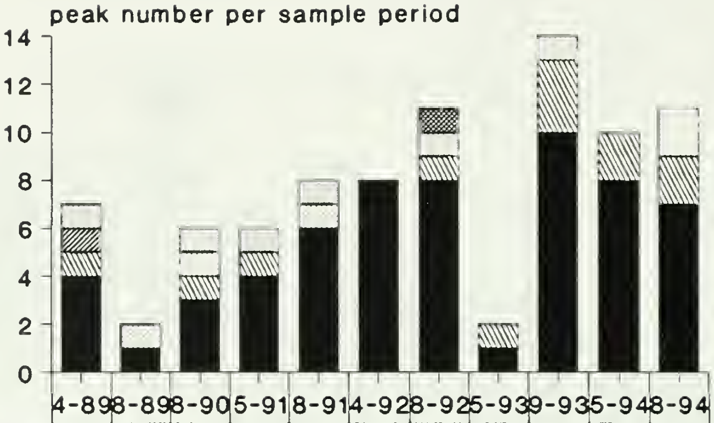
	4-89	8-89	5-90	8-90	5-93	8-93	6-94	8-94
Dipsosaurus								1
Urosaurus	3		1	1	2		2	1
Sceloporus			1	1			1	
Callisaurus				1	1	1		1
Uta	1	7	2	6	1	6	3	6
Cnemidophorus			1	2	4	1	2	2

Figure 20. Peak values for lizard species, Burn Site 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



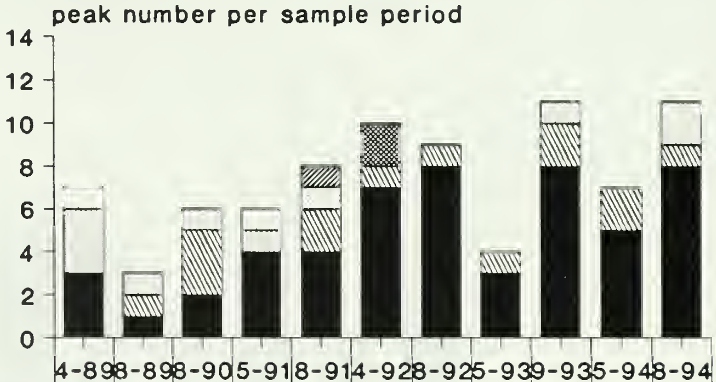
	8-89	5-90	8-90	5-91	5-93	9-93	5-94	8-94
Gambelia					1			
Dipsosaurus	1					1		1
Callisaurus		1	2	1				1
Uta	2	1	3	1		1		6
Cnemidophorus	4	2	3	3	5	6	4	4

Figure 21. Peak values for lizard species, Creosotebush Site 200-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



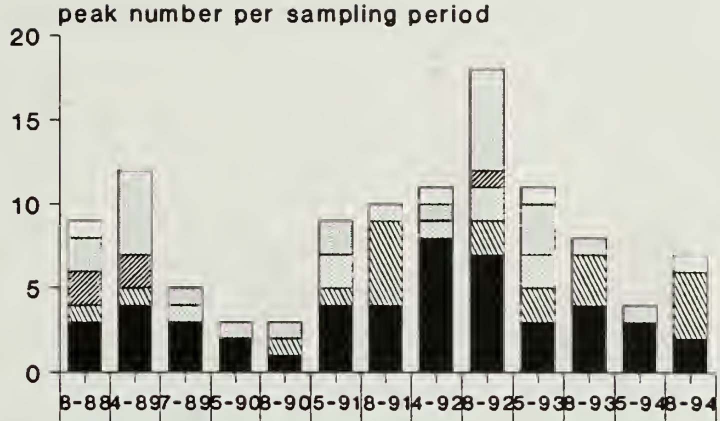
		4-89	8-89	8-90	5-91	8-91	4-92	8-92	5-93	9-93	5-94	8-94
Gambelia								1				
Urosaurus		1		1	1	1		1		1		
Sceloporus		1										
Callisaurus			1	1		1						2
Uta		1		1	1			1	1	3	2	2
Cnemidophorus		4	1	3	4	6	8	8	1	10	8	7

Figure 22. Peak values for lizard species, Dos Lomitas #1 (Inside Exclosure) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



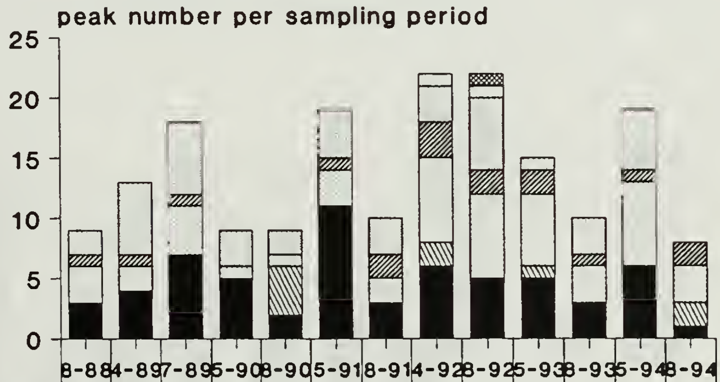
		4-89	8-89	8-90	5-91	8-91	4-92	8-92	5-93	9-93	5-94	8-94
Gambelia							2					
Dipsosaurus		1			1							
Urosaurus		3	1	1	1					1		2
Sceloporus						1						
Callisaurus						1						
Uta			1	3		2	1	1	1	2	2	1
Cnemidophorus		3	1	2	4	4	7	8	3	8	5	8

Figure 23. Peak values for lizard species, Dos Lomitas #2 (Outside Exclosure) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



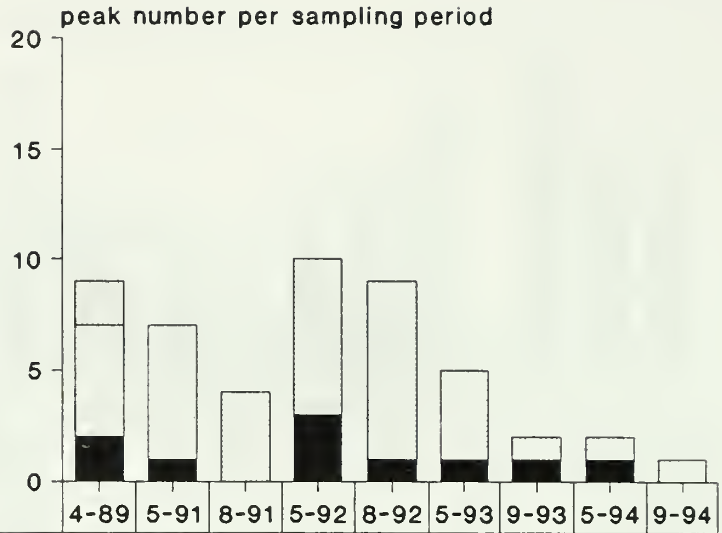
	8-88	4-89	7-89	5-90	8-90	5-91	8-91	4-92	8-92	5-93	8-93	5-94	8-94
Dipsosaurus	1							1		1			1
Urosaurus	2	5	1	1	1	2		1	6	3	1		
Sceloporus	2	2							1				
Callisaurus	0		1			2	1	1	2	2		1	
Uta	1	1			1	1	5		2	2	3		4
Cnemidophorus	3	4	3	2	1	4	4	8	7	3	4	3	2

Figure 24. Peak values for lizard species, East Armenta #1 (Desert scrub) 200-m transect, Organ Pipe Cactus National Monument, Arizona, 1988–1994.



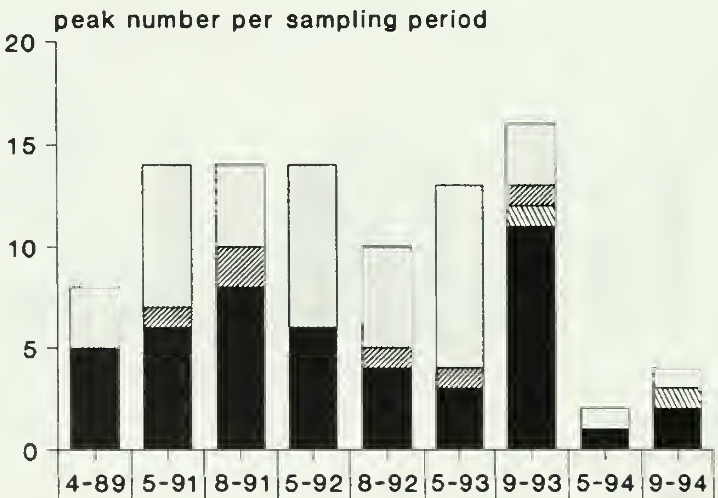
	8-88	4-89	7-89	5-90	8-90	5-91	8-91	4-92	8-92	5-93	8-93	5-94	8-94
Gambelia									1				
Dipsosaurus								1	1				
Urosaurus	2	6	6	3	2	4	3	3	6	1	3	5	
Sceloporus	1	1	1			1	2	3	2	2	1	1	2
Callisaurus	3	2	4	1	1	3	2	7	7	6	3	7	3
Uta					4			2		1			2
Cnemidophorus	3	4	7	5	2	11	3	6	5	5	3	6	1

Figure 25. Peak values for lizard species, East Armenta #2 (Kuakatch Wash) 200-m transect, Organ Pipe Cactus National Monument, Arizona, 1988–1994.



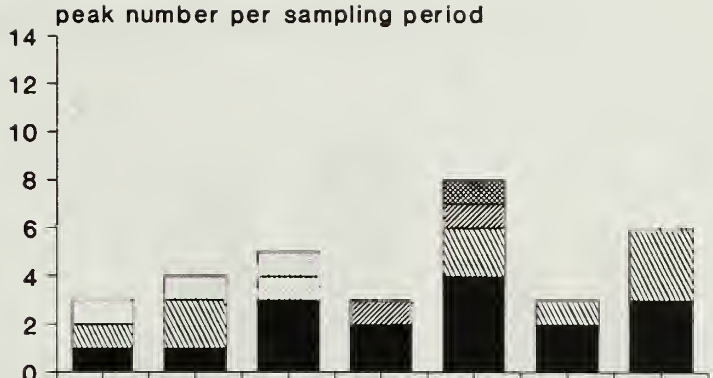
	4-89	5-91	8-91	5-92	8-92	5-93	9-93	5-94	9-94
Urosaurus	2								
Callisaurus	5	6	4	7	8	4	1	1	1
Cnemidophorus	2	1		3	1	1	1	1	

Figure 26. Peak values for lizard species, Growler Canyon #1 (Wash Bed) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



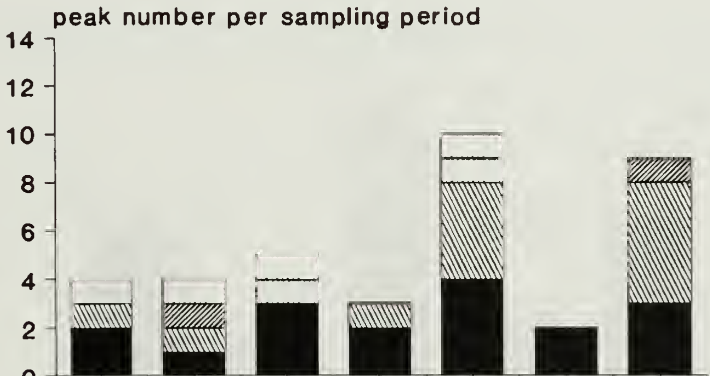
	4-89	5-91	8-91	5-92	8-92	5-93	9-93	5-94	9-94
Urosaurus	3	7	4	8	5	9	3	1	1
Sceloporus		1	2		1	1	1		
Uta							1		1
Cnemidophorus	5	6	8	6	4	3	11	1	2

Figure 27. Peak values for lizard species, Growler Canyon #2 (Bosque) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



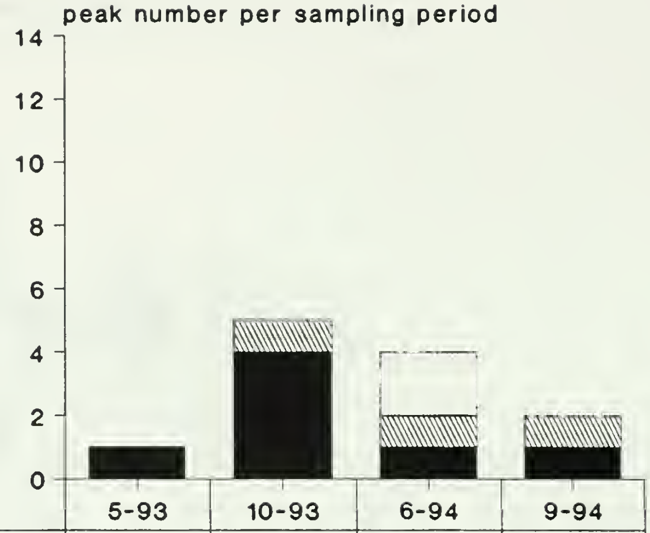
	5-90	7-90	5-91	5-93	8-93	5-94	8-94
Gambelia					1		
Urosaurus			1				
Sceloporus				1	1		
Callisaurus	1	1	1				
Uta	1	2			2	1	3
Cnemidophorus	1	1	3	2	4	2	3

Figure 28. Peak values for lizard species, Lizard Grid #1 (North) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1990–1994.



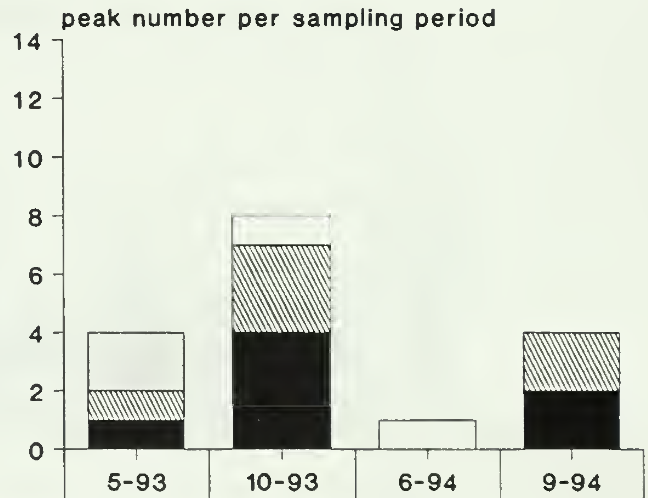
	5-90	7-90	5-91	5-93	8-93	5-94	8-94
Dipsosaurus		1	1		1		
Urosaurus			1				
Sceloporus		1					1
Callisaurus	1				1		
Uta	1	1		1	4		5
Cnemidophorus	2	1	3	2	4	2	3

Figure 29. Peak values for lizard species, Lizard Grid #2 (South) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1990–1994.



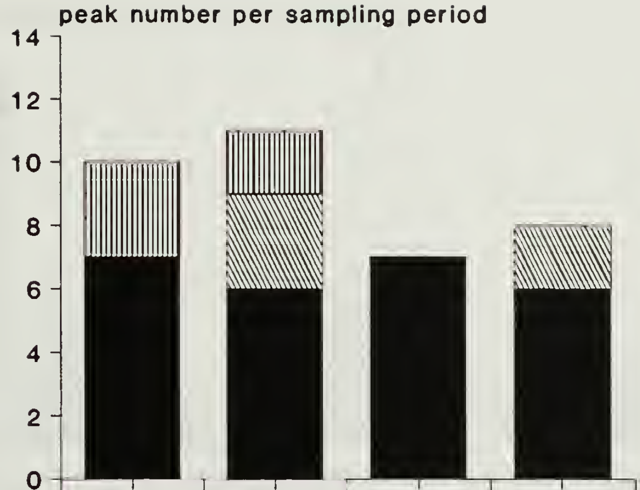
	5-93	10-93	6-94	9-94
Urosaurus ornatus			2	
Uta stansburiana		1	1	1
Cnemidophorus tigris	1	4	1	1

Figure 30. Peak values for lizard species, Lost Cabin #1 (Wash Flats) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1993–1994.



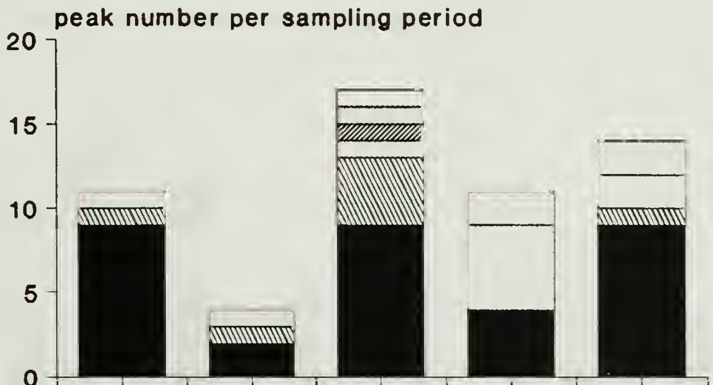
	5-93	10-93	6-94	9-94
Crotaphytus collaris		1	1	
Urosaurus ornatus	2			
Uta stansburiana	1	3		2
Cnemidophorus tigris	1	4		2

Figure 31. Peak values for lizard species, Lost Cabin #2 (Rocky Draw) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1993–1994.



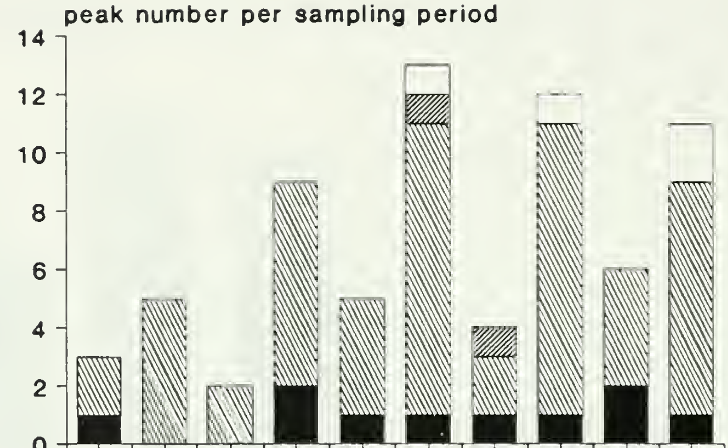
	9-93	9-93	5-94	9-94
Urosaurus graciosus	3	2		
Uta stansburiana		3		2
Cnemidophorus tigris	7	6	7	6

Figure 32. Peak values for lizard species, Lower Colorado Larrea 200-m transect, Organ Pipe Cactus National Monument, Arizona, 1993–1994.



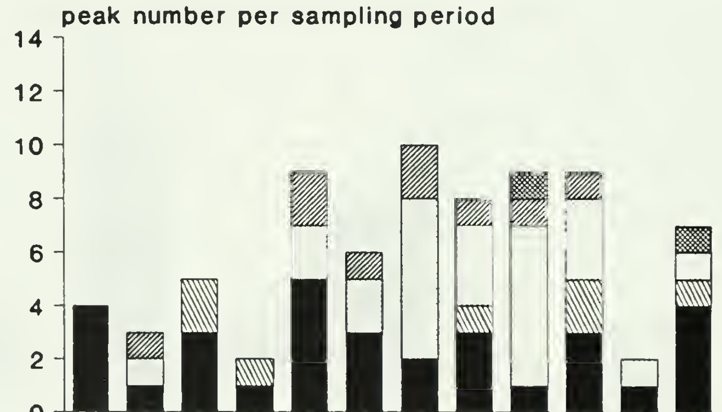
	4-89	5-93	9-93	5-94	8-94
Dipsosaurus			1		
Urosaurus		1	1	2	2
Sceloporus			1		
Callisaurus	1		1	5	2
Uta	1	1	4		1
Cnemidophorus	9	2	9	4	9

Figure 33. Peak values for lizard species, Salsola Site 200-m transect, Organ Pipe Cactus National Monument, Arizona, 1993–1994.



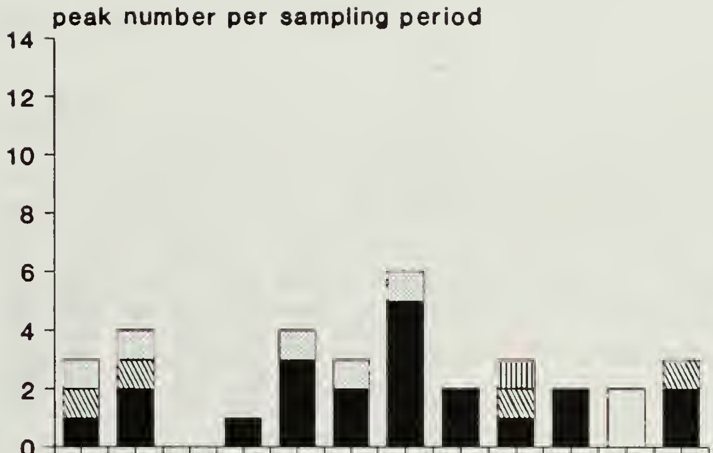
	5-89	8-89	5-91	8-91	5-92	8-92	4-93	9-93	5-94	9-94
Crotaphytus						1		1		2
Sceloporus						1	1			
Uta	2	5	2	7	4	10	2	10	4	8
Cnemidophorus	1			2	1	1	1	1	2	1

Figure 34. Peak values for lizard species, Pozo Nuevo #1 (Hill Base) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



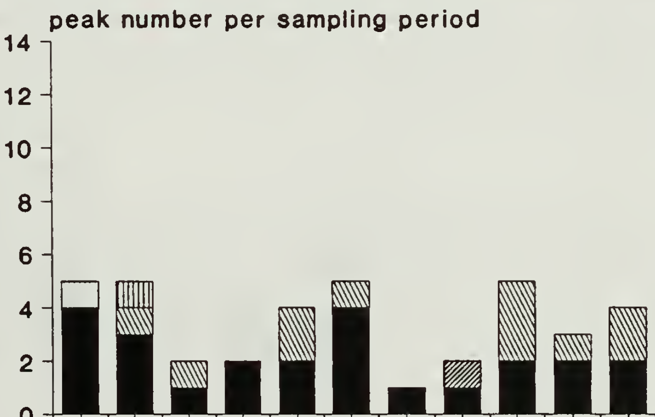
	5-89	8-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	9-94
U. graciosus									1			1
Sceloporus		1			2	1	2	1	1	1		
Callisaurus		1			2	2	6	3	6	3	1	1
Uta			2	1				1		2		1
Cnemidophorus	4	1	3	1	5	3	2	3	1	3	1	4

Figure 35. Peak values for lizard species, Pozo Nuevo #2 (Wash) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



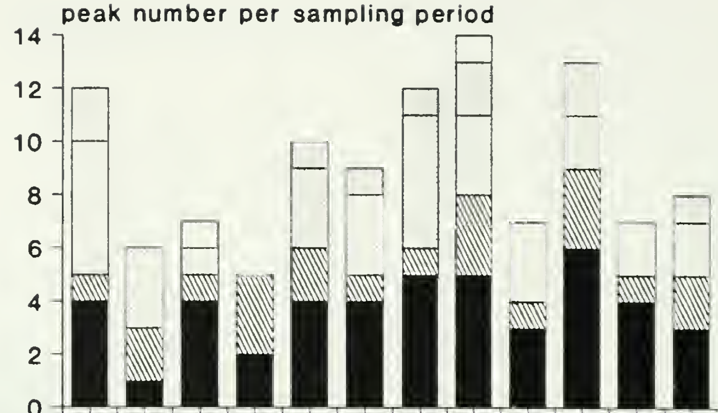
	5-89	8-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	9-94
Heloderma									1			
Callisaurus	1	1			1	1	1				2	
Uta	1	1							1			1
Cnemidophorus	1	2		1	3	2	5	2	1	2		2

Figure 36. Peak values for lizard species, Pozo Nuevo #3 (*dumosa* Bursage) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



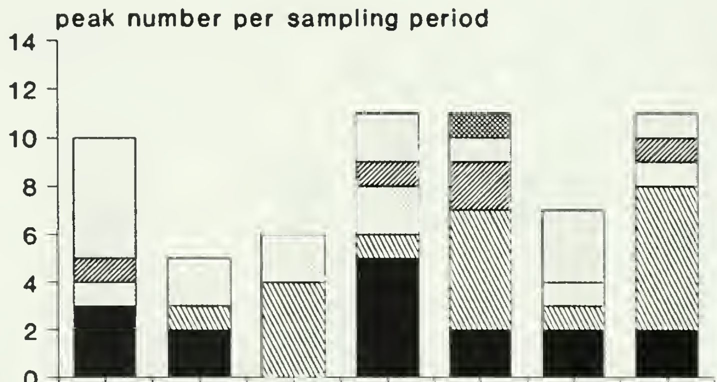
	5-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	9-94
Phrynosoma solare		1									
Sceloporus								1			
Callisaurus	1										
Uta		1	1		2	1			3	1	2
Cnemidophorus	4	3	1	2	2	4	1	1	2	2	2

Figure 37. Peak values for lizard species, Pozo Nuevo #4 (*deltoidea* Bursage) 100-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



	5-89	8-89	5-90	8-90	5-91	8-91	4-92	8-92	4-93	9-93	5-94	9-94
Dipsosaurus			1					1				
Urosaurus	2				1	1	1	2		2		1
Callisaurus	5	3	1		3	3	5	3	3	2	2	2
Uta	1	2	1	3	2	1	1	3	1	3	1	2
Cnemidophorus	4	1	4	2	4	4	5	5	3	6	4	3

Figure 38. Peak values for lizard species, Senita Basin 250-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.



	4-89	8-89	8-90	5-93	8-93	5-94	9-94
Gambelia					1		
Urosaurus	5			2	1	3	1
Sceloporus	1			1	2		1
Callisaurus	1	2	2	2		1	1
Uta		1	4	1	5	1	6
Cnemidophorus	3	2		5	2	2	2

Figure 39. Peak values for lizard species, Vulture Site 200-m transect, Organ Pipe Cactus National Monument, Arizona, 1989–1994.

Nocturnal Rodents

Introduction

Nocturnal rodent population assessment and monitoring has been shown to be an efficient way to document and monitor overall habitat conditions in the Sonoran Desert. By serving as a major prey base for bird, reptile, and mammal predators, as well as fulfilling an important role in soil aeration and seed dispersal, nocturnal rodents and their known population dynamics can serve as a tool for making assessments of general ecosystem health. Nocturnal rodents are particularly efficient to study because they (1) are found in most habitats, (2) respond quickly to changes in the primary production of plants, (3) can have several litters in a year, (4) are easily captured, (5) have a relatively small home range, (6) can be captured repeatedly in the same area, and (7) are easily identified (Petryszyn and Russ 1995).

Project History

In the Special Status Mammals of the ORPI SEP project, contracted to Yar Petryszyn (The University of Arizona), baseline information was collected on nocturnal rodent densities and distributions over a diverse array of macro and microhabitats within the monument. Although several inventories of mammals existed before this study (Mearns 1907; Cockrum 1981; Cockrum and Petryszyn 1986), this was the first effort to make population assessments of nocturnal rodents over wide-ranging habitats in the monument.

Field work began in 1987 and consisted of establishing and sampling permanent rodent grids located on each of 16 (at that time) study sites. Additionally, at most sites 1 or 2 pitfall traps (3-lb. coffee cans) were placed to capture desert shrews *(Notiosorex crawfordi).* Large Havahart traps were set for the capture of larger animals such as badger *(Taxidea taxus),* ringtail *(Bassariscus astutus),* foxes, and skunks.

Two families of nocturnal rodents are present in the monument: Cricetidae and Heteromyidae. Results from this study showed that the heteromyids, pocket mice *(Chaetodipus* and *Perognathus* spp.*)* and kangaroo rats *(Dipodomys* spp.*),* strongly dominated bajada and valley fill macrohabitats. The cricetids, represented by the white-throated woodrat *(Neotoma albigula)* and the cactus mouse *(Peromyscus eremicus)*, were the main small mammal constituents of mountain canyon macrohabitats. During the course of this study, the Arizona cotton rat *(Sigmodon arizonae)*, was confirmed on the monument for the first time in December 1988.

As a final part of the study, monitoring protocols were developed to guide ORPI resource management staff in monitoring nocturnal rodent populations through time.

1994 Monitoring Activities

For a 4-week period from 28 June through 22 July, nocturnal rodents were monitored by resource management staff on 13 EMP study sites.

Methods

Nocturnal rodents were monitored using capture, mark, release, and recapture methods (Petryszyn and Russ 1995). Forty-nine 3 x 3.5 x 9-in. Sherman live-traps were baited with oat flakes and set on each of the 2 mammal grids (Bull Pasture has only 1 grid) located at each study site. Trap stations on each grid were given permanent alphanumeric designations of A1 through G7 (A1 = southwest grid corner; G7 = northeast grid corner). This designation is useful in tracking species microhabitat selection and species distribution over time. Trapping was conducted during 2 consecutive nights with rodent processing (weighing, sexing, and marking), beginning near dawn.

Biomass and densities were estimated using the assumption that 72% of the rodent population existing on the sampling grid (effective sampling area = 1.4 ha) is captured during the 2-night trapping period (Petryszyn and Russ 1995). Species diversity was determined from the formula:

$$\mathbf{H' = - SUM\ (p_i\ x\ ln(p_i))},$$

where H' is diversity, p_i is, for each species i, the numerical proportion of that species abundance (N, density) to the total abundance of all rodents on the quadrant or sample and ln is the natural logarithm. Field techniques and population modelling methods followed are explained in detail in the monitoring handbook.

Results

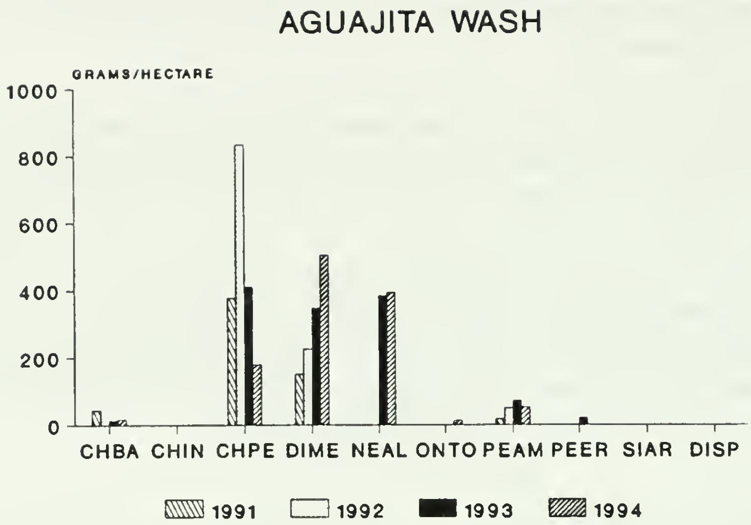
During this 4-week trapping period, 1,017 individual rodents (excluding recaptures and the few individuals that escaped before being processed) were captured in 2,450 trap nights (49 traps/grid/night), representing 9 species. Estimated total biomass (cricetids and heteromyids) ranged from 357.7 g at Senita Basin to 3,514.6 g at Bull Pasture. Figures 40–52 contain summaries of monitoring results.

There was an obvious decline in the number of small heteromyids, especially the desert pocket mouse *(Chaetodipus penicillatus)*, that were captured this year on many of the quadrats. Along with this decline there was usually a corresponding marked increase in the numbers of Merriam's kangaroo rat *(Dipodomys merriami)* captured. This trend was seen on many of the quadrats occurring on bajada and valley fill study sites. At least one valley fill site (Growler Canyon) that has quadrats both in the open and in nearby mesquite bosques, this trend was not as readily observed, as the desert pocket mouse living in these more mesic and vegetatively dense areas apparently did not fare so badly. On some valley fill sites (Lower Colorado Larrea and Armenta Ranch), there was a twofold increase in *D. merriami*, but not a significant decrease in small heteromyids. No Arizona cottonrats were captured this year.

Senita Basin continued to produce inexplicably low biomass and density of rodents. Nearby Lost Cabin EMP site, which is very similar to Senita Basin in terms of vegetation structure, soils and topography, was monitored for the first time this year. This site produced comparable results with respect to species composition, biomass and density.

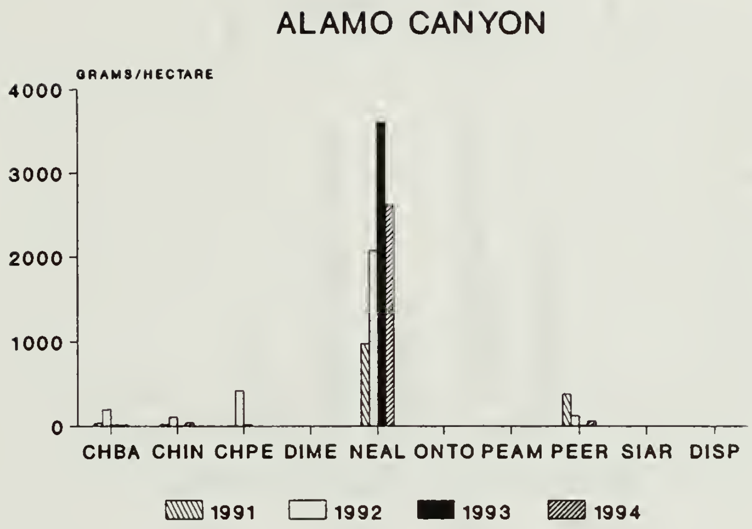
The problem of ants removing bait before rodents could get into the trap was significant on a few sites. Ants emptied bait from 24 of 49 traps on 1 quadrat at the Growler Canyon site. Experimentation with a higher bulk density bait such as millet or bird seed in areas that support high ant activity might be warranted.

Note: Figures 40–52 display density and biomass estimates for small nocurnal rodents observed on the Ecological Monitoring Program sites in Organ Pipe Cactus National Monument, 1991–1994. The following species abbreviations are used: **CHBA** = Bailey's pocket mouse *(Chaetodipus baileyi)*, **CHIN** = rock pocket mouse *(Chaetodipus intermedius)*, **CHPE** = desert pocket mouse *(Chaetodipus penicillatus)*, **DIME** = Merriam's kangaroo rat *(Dipodomys merriami)*, **DISP** = bannertail kangaroo rat *(Dipodomys spectabilis)*, **NEAL** = white-throated woodrat *(Neotoma albigula)*, **ONTO** = southern grasshopper mouse *(Onychomys torridus)*, **PEAM** = Arizona pocket mouse *(Perognathus amplus)*, **PEER** = cactus mouse *(Peromyscus eremicus)*, and **SIAR** = Arizona cotton rat *(Sigmodon arizonae)*.



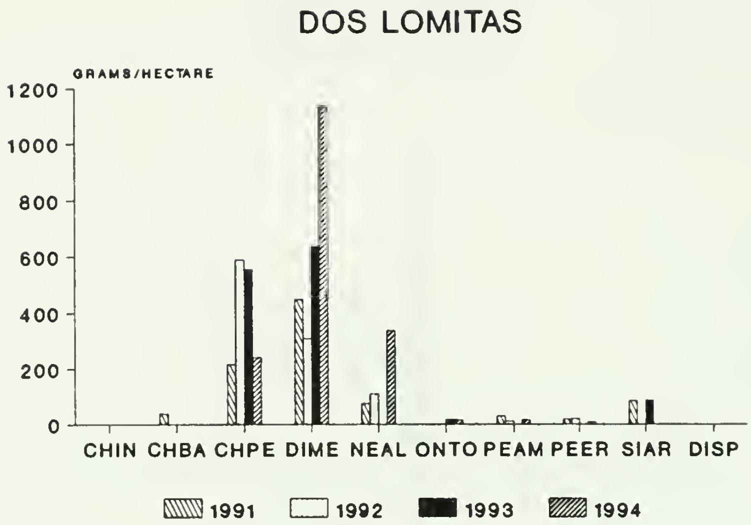
	1991	1992	1993	1994
Total Heteromyid				
Density (n/ha)	34.5	61.0	43.0	31.0
Biomass (g/ha)	586.8	1,105.4	842.5	753.95
Total Cricetid				
Density (n/ha)	0.0	0.0	4.0	3.5
Biomass (g/ha)	0.0	0.0	402.8	404.95
Diversity (H')	0.743	0.577	1.226	1.34 7
Capture success (night 1)	30%	67%	52%	40%
Capture success (night 2)	63%	83%	63%	49%
Recapture	36%	31%	31%	38%

Figure 40. Density and biomass estimates for small nocturnal mammals observed on the Aguajita sites, Organ Pipe Cactus National Monument, Arizona, 1991–1994.



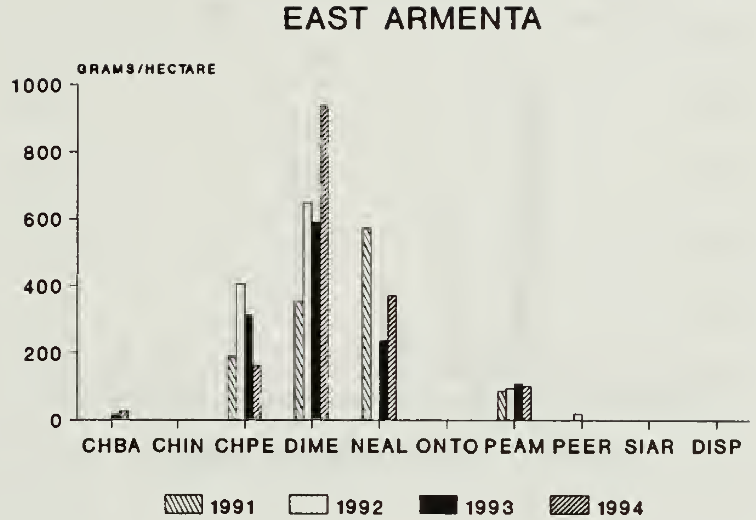
	1991	1992	1993	1994
Total Heteromyid				
Density (n/ha)	3.5	34.0	2.0	4.0
Biomass (g/ha)	64.8	725.2	39.3	57.5
Total Cricetid				
Density (n/ha)	28.5	25.0	26.0	20.5
Biomass (g/ha)	1,353.3	2,189.5	3,602.8	2,677.2
Diversity (H')	0.963	1.458	0.420	0.855
Capture success (night 1)	32%	64%	34%	27%
Capture success (night 2)	49%	78%	41%	39%
Recapture	31%	28%	41%	38%

Figure 41. Density and biomass estimates for nocturnal rodents observed on the Alamo Canyon site, Organ Pipe Cactus National Monument, Arizona, 1991–1994.



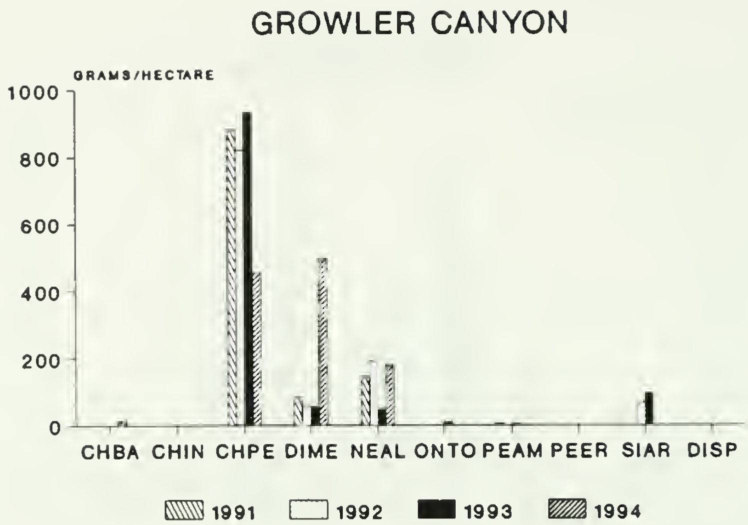
	1991	1992	1993	1994
Total Heteromyid				
Density (n/ha)	31.5	45.5	51.0	48.0
Biomass (g/ha)	738.1	909.5	1,189.7	1,391.2
Total Cricetid				
Density (n/ha)	2.5	2.0	2.5	3.5
Biomass (g/ha)	182.7	133.4	107.2	363.7
Diversity (H')	1.275	0.762	0.827	1.011
Capture success (night 1)	33%	46%	69%	56%
Capture success (night 2)	52%	71%	69%	71%
Recapture	29%	29%	42%	31%

Figure 42. Density and biomass estimates for nocturnal rodents observed on the Dos Lomitas site, Organ Pipe Cactus National Monument, Arizona, 1991–1994.



	1991	1992	1993	1994
Total Heteromyid				
Density (n/ha)	30.0	53.5	45.0	48.5
Biomass (g/ha)	626.2	1146.7	1025.1	1228.35
Total Cricetid				
Density (n/ha)	4.0	1.0	2.0	2.5
Biomass (g/ha)	570.5	19.9	236.5	371.0
Diversity (H')	1.309	1.080	1.231	1.186
Capture success (night 1)	43%	73%	58%	69%
Capture success (night 2)	47%	73%	62%	63%
Recapture	43%	49%	39%	45%

Figure 43. Density and biomass estimates for nocturnal rodents observed on the East Armenta site, Organ Pipe Cactus National Monument, Arizona, 1991–1994.

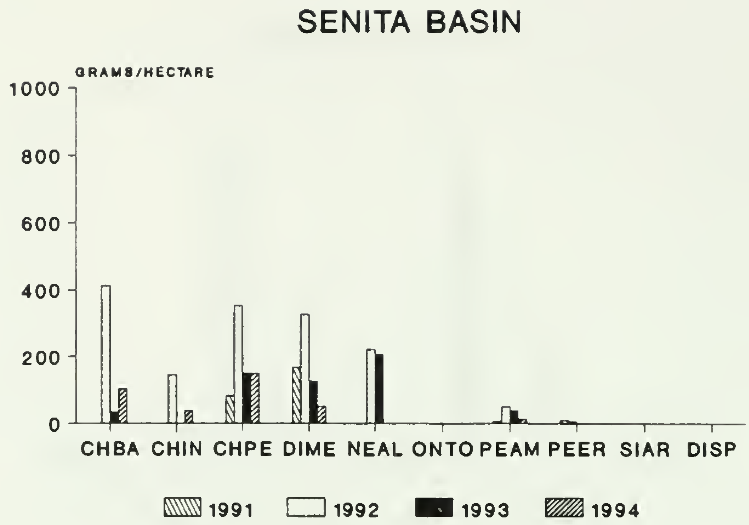


	1991	1992	1993	1994
Total Heteromyid				
Density (n/ha)	56.0	53.0	61.5	44.0
Biomass (g/ha)	969.7	880.0	992.6	963.3
Total Cricetid				
Density (n/ha)	1.0	1.5	3.0	1.0
Biomass (g/ha)	145.4	258.6	156.5	180.5
Diversity (H')	0.317	0.269	0.410	0.783
Capture success (night 1)	62%	55%	82%	54%
Capture success (night 2)	67%	81%	73%	56%
Recapture	19%	31%	32%	30%

Figure 44. Density and biomass estimates for nocturnal rodents observed on the Growler Canyon site, Organ Pipe Cactus National Monument, Arizona, 1991–1994.

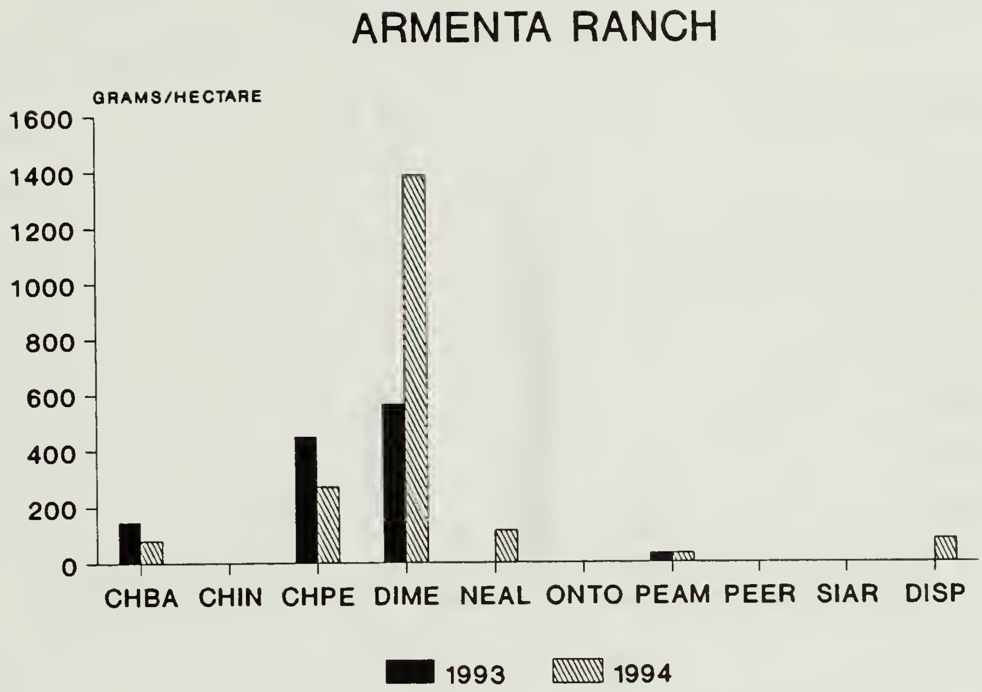
	1991	1992	1993	1994
Total Heteromyid				
Density (n/ha)	49.0	52.5	39.0	37.0
Biomass (g/ha)	1,073.7	1,030.0	993.6	1,069.1
Total Cricetid				
Density (n/ha)	0.0	1.0	1.0	0.5
Biomass (g/ha)	0.0	19.5	20.6	9.25
Diversity (H')	1.063	1.204	1.102	0.726
Capture success (night 1)	60%	77%	48%	59%
Capture success (night 2)	66%	55%	58%	51%
Recapture	41%	41%	42%	68%

Figure 45. Density and biomass estimates for nocturnal rodents observed on the Pozo Nuevo site. Organ Pipe Cactus National Monument, Arizona, 1991–1994.



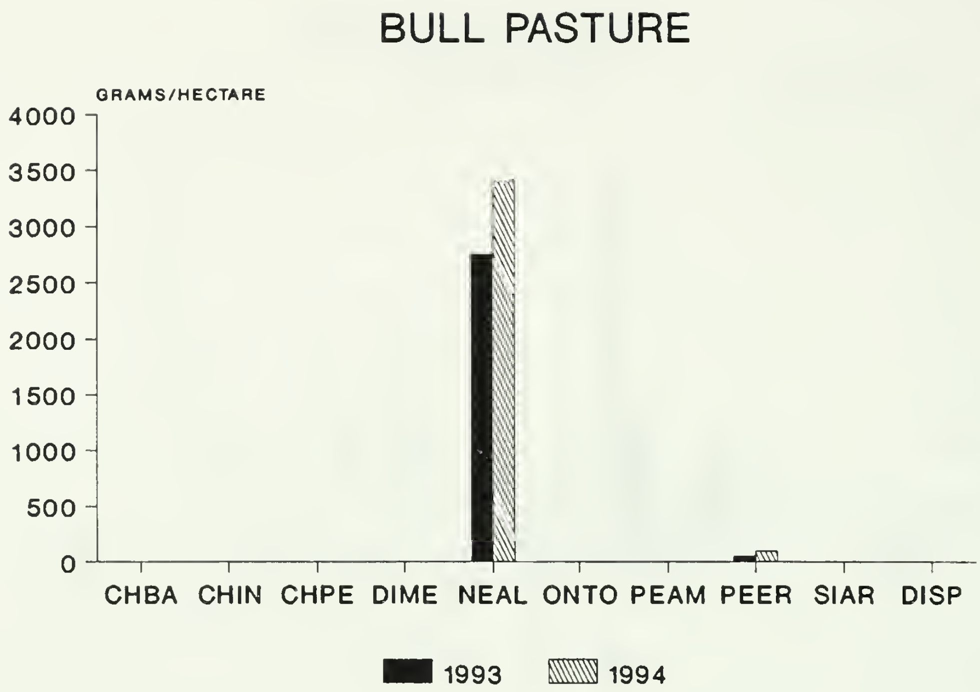
	1991	1992	1993	1994
Total Heteromyid				
Density (n/ha)	10.5	63.5	15.5	18.0
Biomass (g/ha)	265.9	1,288.9	349.9	357.7
Total Cricetid				
Density (n/ha)	0.5	2.0	1.5	0.0
Biomass (g/ha)	9.4	228.7	206.0	0.0
Diversity (H')	1.006	1.575	1.367	1.386
Capture success (night 1)	8%	72%	17%	15%
Capture success (night 2)	17%	88%	20%	23%
Recapture	17%	30%	10%	1%

Figure 46. Density and biomass estimates for nocturnal rodents observed on the Senita Basin site, Organ Pipe Cactus National Monument, Arizona, 1991–1994.



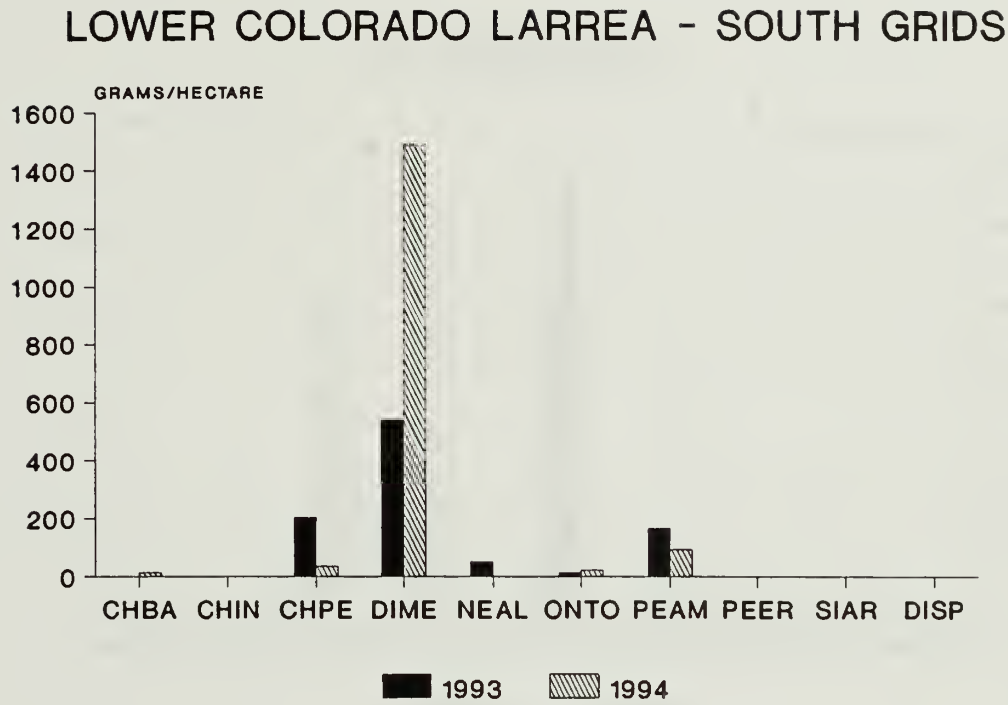
	1993	1994
Total Heteromyid		
Density (n/ha)	50.0	61.0
Biomass (g/ha)	1,193.6	1,854.90
Total Cricetid		
Density (n/ha)	0.0	1.0
Biomass (g/ha)	0.0	115.5
Diversity (H')	1.087	1.076
Capture success (night 1)	54%	78%
Capture success (night 2)	59%	79%
Recapture	19%	38%

Figure 47. Density and biomass estimates for nocturnal rodents observed on the Armenta Ranch site, Organ Pipe Cactus National Monument, Arizona, 1993–1994.



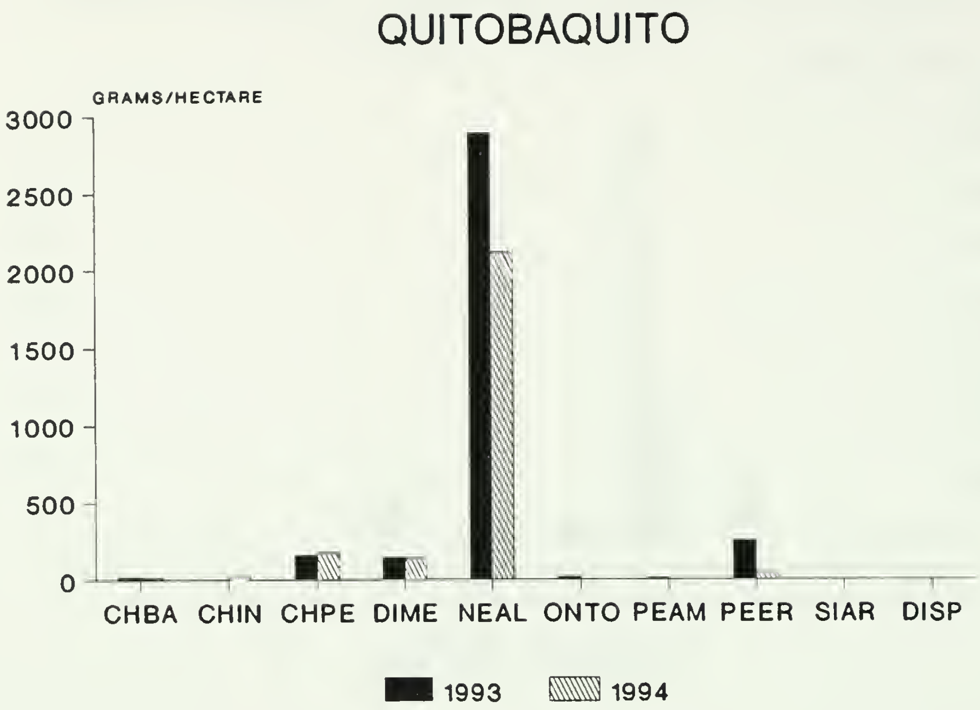
	1993	1994
Total Heteromyid		
Density (n/ha)	0.0	0.0
Biomass (g/ha)	0.0	0.0
Total Cricetid		
Density (n/ha)	24.0	31.0
Biomass (g/ha)	2,795.9	3,514.6
Diversity (H')	0.377	0.491
Capture success (night 1)	33%	35%
Capture success (night 2)	31%	47%
Recapture	47%	39%

Figure 48. Density and biomass estimates for nocturnal rodents observed on the Bull Pasture site, Organ Pipe Cactus National Monument, Arizona, 1993–1994.



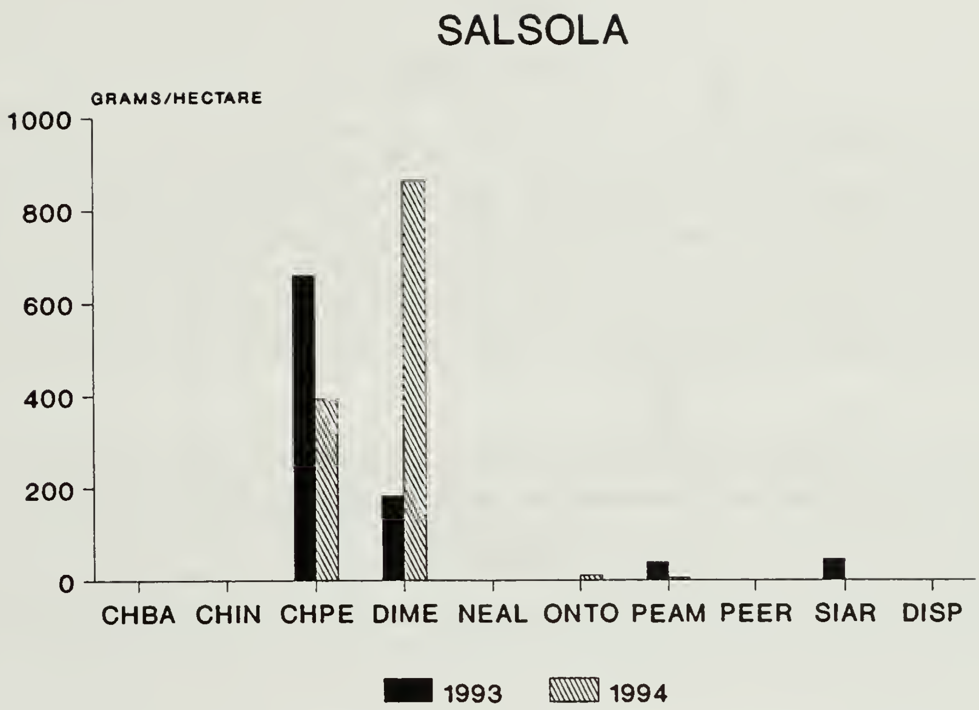
	1993	1994
Total Heteromyid		
Density (n/ha)	41.0	51.5
Biomass (g/ha)	910.0	1,632.3
Total Cricetid		
Density (n/ha)	1.0	1.0
Biomass (g/ha)	65.5	22.9
Diversity (H')	1.200	0.719
Capture success (night 1)	43%	63%
Capture success (night 2)	54%	67%
Recapture	20%	35%

Figure 49. Density and biomass estimates for nocturnal rodents observed on the Lower Colorado Larrea site, Organ Pipe Cactus National Monument, Arizona, 1993–1994.



	1993	1994
Total Heteromyid		
Density (n/ha)	17.0	18.5
Biomass (g/ha)	327.9	355.1
Total Cricetid		
Density (n/ha)	52.5	18.0
Biomass (g/ha)	3,157.9	2,159.1
Diversity (H')	1.401	1.373
Capture success (night 1)	69%	46%
Capture success (night 2)	77%	46%
Recapture	45%	40%

Figure 50. Density and biomass estimates for nocturnal rodents observed on the Quitobaquito site, Organ Pipe Cactus National Monument, Arizona, 1993–1994.



	1993	1994
Total Heteromyid		
Density (n/ha)	50.5	48.5
Biomass (g/ha)	881.9	1,259.2
Total Cricetid		
Density (n/ha)	0.5	0.5
Biomass (g/ha)	45.5	11.5
Diversity (H')	0.637	0.793
Capture success (night 1)	54%	62%
Capture success (night 2)	73%	66%
Recapture	31%	45%

Figure 51. Density and biomass estimates for nocturnal rodents observed on the Salsola site, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

LOST CABIN

	1994
Total Heteromyid	
Density (n/ha)	29.5
Biomass (g/ha)	473.7
Total Cricetid	
Density (n/ha)	0.0
Biomass (g/ha)	0.0
Diversity (H')	0.497
Capture success (night 1)	30%
Capture success (night 2)	38%
Recapture	19%

Figure 52. Density and biomass estimates for nocturnal rodents observed on the Lost Cabin site, Organ Pipe Cactus National Monument, Ariona, 1994.

Birds

Introduction

There are 277 species of birds known to occur, or to have occurred, within ORPI (Groschupf et al. 1988). Of these, 63 are known to breed there. Bird studies in the monument date back to 1941, when Huey (1942) wrote an annotated checklist of 150 bird species. Later studies reported on ecology and general habitat relationships of breeding birds within the monument (Philips and Pulich 1948; Hensley 1959). Studies focusing on the ecology and distribution of selected species or populations continued through the early 1980s (Cole and Whiteside 1965; Beck et al. 1973; Inouye et al. 1981).

Ecologists generally agree that baseline assessment and long-term monitoring of bird populations can provide a good tool for measuring ecological change over time. The Ecology of Special Status Avian Species, one of the 12 original SEP research projects, was initiated in 1987 to provide this kind of baseline information on bird population parameters. As a part of the investigation, conducted by R. Roy Johnson (Cooperative Park Studies Unit/The University of Arizona, CPSU/UA), monitoring protocols were designed for use by ORPI resource management staff.

Project History

In this study, baseline assessments were made of bird population structure, relative abundances, and species richness at the EMP study sites. In addition, factors that account for variation in bird communities of specific habitats over time were investigated, and monitoring protocols were designed to measure these changes. In the initial research phase of the project, various means of sampling bird populations on the study sites were investigated. By the end of the 1987 field season, an appropriate censusing methodology, a comparable database, and an outline for future censuses had been produced. Monitoring protocols were further refined and tested by the principal investigator through the 1989 census. A preliminary project closeout meeting was held with Johnson in April 1992. A training session in monitoring methodology was provided to the resource management staff then.

Although the draft monitoring protocols were partially implemented and tested by resource management staff at the 7 Core I and non-Core I EMP sites in 1991, and again in 1992 during the training session with Johnson, neither of these outings are to be considered valid censuses, since certain monitoring protocol rules were violated. The 1993 monitoring session was a valid census, as it was conducted in full accordance with protocol requirements.

1994 Monitoring Activities

From 11 April through 23 May, birds were censused by resource management monitoring staff. This work was conducted on 7 EMP study sites.

Methods

The monitoring protocol is designed to obtain information on relative abundances of all breeding birds on EMP study sites during breeding periods (Johnson and Hiett 1992). This is done by censusing birds within belt transects, with the belt width varying and dependent on the particular study site. Most transects are 40 m wide. In the narrow, thickly vegetated riparian areas (Growler Canyon, Aguajita Wash, and Alamo Canyon) transect widths are approximately 20 m. Almost all transects are 1,000 m long.

Standard pre-census preparation included conducting practice censuses in mixed Sonoran Desert scrub and xeroriparian habitats. Bird vocalization audio-tapes were extensively used both before and during the census so that the observer could maintain a familiarity with calls and songs from breeding birds, winter residents, and transients.

Censusing began near sunrise on all sites. While walking down the transect line, direct counts were made on all birds heard or seen within the transect. Observations on behavior, and if possible, age and sex, were recorded on the field forms. Birds occurring off the transects were recorded but were not used in relative abundance and species richness estimates.

Three censuses, each census considered a sample replicate, were made at each study site. According to the monitoring protocol, a minimum of 3 censuses is needed to statistically estimate data reliability. The sample replicates were spaced at approximately 3-week intervals. One observer conducted all censuses at all sites. The methods followed during this monitoring period are detailed in the monitoring handbook (Johnson 1995).

At the February 1994 EMPAC meeting, plans were made to implement point counts at 2 EMP sites. The results from these surveys could then be compared with standard belt transect findings (Table 5). After consulting with Kathy Hiett (CPSU/UA), 2, 50-m-radius circular plots were set up approximately 300 m apart at the East Armenta and Senita Basin study sites. All point count replicates, except for 1, were conducted within 1 day of the belt transect replicates conducted on those 2 sites. In each of the 10-minute counts conducted, which began 5 minutes after the observer arrived on the plot, direct counts were made on all bird species within the plot. Distance and azimuth estimates to the bird were also recorded to allow spot mapping.

In all censuses, special effort was made to avoid duplicating counts. Some bird species such as the verdin *(Auriparus flaviceps)*, black-tailed gnatcatcher *(Polioptila melanura)*, curve-billed thrasher *(Toxostoma curvirostre)* and Lucy's warbler *(Vermivora luciae)* tend to stay in a fairly small area, thus allowing individuals to be tracked relatively easily. Those species, however, that tend to be wider-ranging, like gila woodpecker *(Melanerpes uropygialis)*, Myiarchus flycatchers *(Myiarchus* spp.*)*, orioles *(Icterus* spp.*)*, and northern flicker *(Colaptes auratus)* demand that a censuser pay close attention to the movement of these birds around the study site area so that duplicate counts are minimized.

If there were questions as to a bird species identity, it was listed as "unknown." Two species of Myiarchus flycatchers occur in the monument, ash-throated flycatcher *(Myiarchus cinerascens)* and brown-crested flycatcher *(Myiarchus tyrannulus)*. Because of similarities in physical and behavioral characteristics between the 2 species, identification was sometimes difficult. Because

Table 5. A comparison of results between point count and belt transect bird census methods at 2 study sites, Organ Pipe Cactus National Monument, Arizona.

	East Armenta			Senita Basin		
	Point Count		Belt transect	Point Count		Belt transect
	Plot 1	Plot 2		Plot 1	Plot 2	
Species Richness	5.0	7.3	13.7	4.7	4.7	13.3
H' Diversity	1.55	1.80	2.35	1.45	1.44	2.41

Species diversity was determined from the formula:

$$H' = - SUM (p_i \times \ln(p_i)),$$

where H' is diversity, p_i is, for each bird species i, the numerical proportion of that species abundance (N, density) to the total abundance of all bird species on the transect, and ln is the natural logarithm.

of this, sightings were lumped into *Myiarchus* spp. All cowbird sightings were tabulated as "cowbird." Though bronzed cowbird *(Molothrus aeneus)* does occur in the monument primarily near the south boundary close to Mexican agricultural fields, brown-headed cowbirds *(Molothrus ater)* are probably far more abundant monumentwide. "Unknowns" were counted as individual species in richness and diversity tabulations only if it was certain that the bird species were different from all others observed during that particular census. For example, during a census that recorded both white-winged doves *(Zenaida asiatica)* and mourning doves *(Zenaida macroura)*, a field recording of "unknown dove" would be tallied with either white-winged or mourning dove for the above tabulations, since only these 2 species of doves could reasonably be expected to occur on the plot.

Results

The number of birds censused on the 7 study sites over 3 replicates averaged 519 individuals. Fifty-three bird species were recorded. Of these, 33 are known to breed on the monument.

Gambel's quail *(Callipepla gambellii)* numbers on many sites were probably underestimated. Because this species typically remains on the ground as the censuser passes, many individuals likely escape detection during counts.

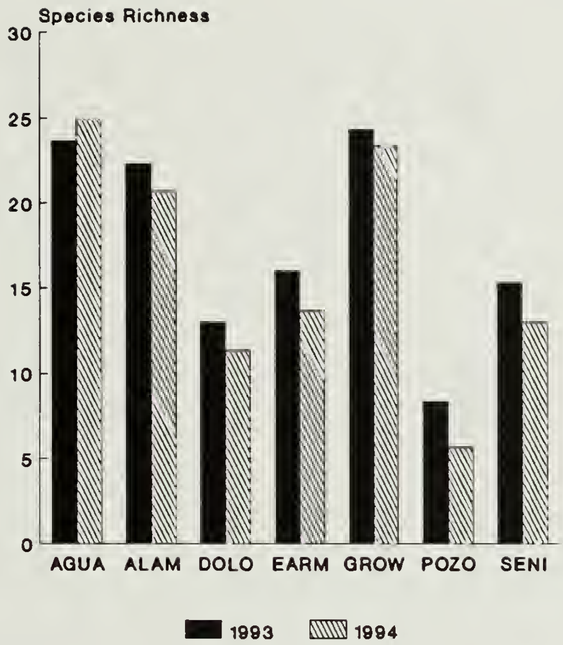
The results from the point counts showed consistently less relative abundance, species richness, and species diversity than were recorded on the belt transect censuses (Table 5). There was also

much higher variation in species counts of common breeding birds between the point count replicates and belt transects.

A possible expanation for the difference in results might be that the time period from when the censuser arrived on-site to when the point count census began (5 minutes) was too long. On-site birds tended to be more visible and active when the censuser first arrived. As time passed during the waiting period, birds generally became more difficult to detect. It is always conceivable, in addition, that duplicate counts were made. In fact, re-counting individuals is an inherent danger in belt transect methods. Point counts are designed to minimize this effect. Last but not least, the time spent conducting the belt transects averaged approximately 1 hour, while point count replicates were only 10 minutes long.

Relative abundances of common birds on the xeroriparian study sites at Organ Pipe Cactus National Monument such as Bell's vireo (*Vireo bellii*), Lucy's warbler, northern cardinal (*Cardinalis cardinalis*), canyon towhee (*Pipilo fuscus*), verdin, and black-tailed gnatcatcher did not change noticeably from the 1993 census. Common birds of the desert scrub habitat such as gila woodpecker, Myiarchus flycatchers, verdin, cactus wren (*Campylorhynchus brunneicappillus*), curve-billed thrasher, or black-tailed gnatcatcher did not show any substantial change in relative abundance from the 1993 census. One striking observation was the lack of northern mockingbird (*Mimus polyglottos*) on most of the transects in 1994. In 1994, northern mockingbird was observed on only 2 of 21 sample replicates conducted on 7 study sites at a mean relative abundance of 0.09 individuals per study site. During the same sample time period in 1993, this species was observed on 12 of the 21 replicates conducted on the the same 7 sites, at a mean abundance of 2.67 individuals per study site. In 1994, no individuals of this species were observed on the study sites after 22 April, while during 1993 observations were still being made near the conclusion of monitoring on 29 May.

Species richness values and diversity values were very similar for most of the sites between 1993 and 1994 (Fig. 53). Species richness, as well as diversity, was consistently higher at the study sites located in xeroriparian areas, as may be expected. The results from this census are organized by study site and are presented in Table 6.



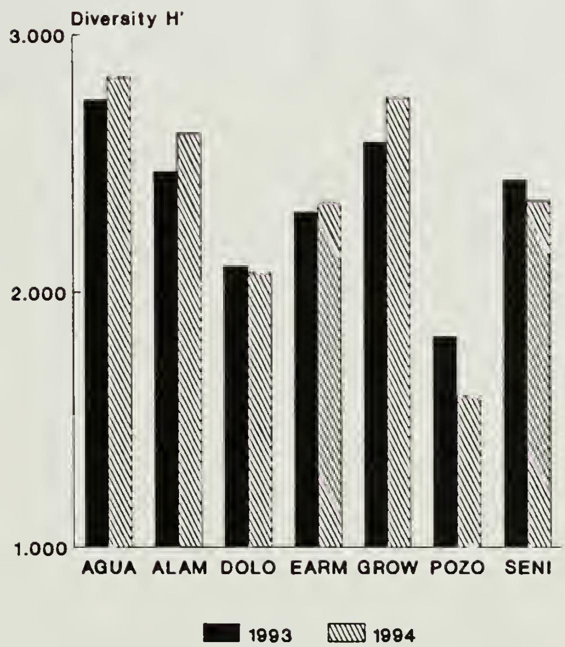


Figure 53. Bird species richness and diversity values recorded on 7 study sites in Organ Pipe Cactus National Monument, Arizona, 1993–1994. The following abbreviations are used: **AGUA** = Aguajita Wash, **ALAM** = Alamo Canyon, **DOLO** = Dos Lomitas, **EARM** = East Armenta, **GROW** = Growler Wash, **POZO** = Pozo Nuevo, **SENI** = Senita Basin.

Table 6. Summary of avian species monitoring on 7 study sites at Organ Pipe Cactus National Monument, Arizona, 1994. Values in table are mean abundance per census (n=3 censuses) ± 1 standard error.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East of Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
Turkey vulture *Cathartes aura*	0.7 ± 0.5				5.3 ± 2.0		
American kestrel *Falco sparverius*	0.3 ± 0.3						
Unknown raptor				0.3 ± 0.3			
Gambel's quail *Callipepla gambellii*	12.7 ± 1.2	1.3 ± 0.7	7.3 ± 1.9	1.3 ± 0.5	5.0 ± 1.6		2.0 ± 1.6
White-winged dove *Zenaida asiatica*	19.3 ± 3.0	5.3 ± 1.0	2.3 ± 1.2	1.7 ± 1.4	18.3 ± 1.9	0.3 ± 0.3	6.3 ± 3.1
Mourning dove *Zenaida macroura*	1.7 ± 0.5	1.0 ± 0.8	8.0 ± 3.3	0.3 ± 0.3	7.7 ± 2.8	2.0 ± 0.9	1.3 ± 1.1
Unknown dove				0.3 ± 0.3	0.7 ± 0.5		
Greater roadrunner *Geococcyx californianus*	0.3 ± 0.3						
Western screech-owl *Otus kennicottii*					0.3 ± 0.3		
White-throated swift *Aeronautes saxatalis*		0.7 ± 0.5					1.3 ± 1.1
Unknown swift					0.3 ± 0.3		
Unknown hummingbird	0.7 ± 0.5	5.0 ± 1.7			2.7 ± 1.1		2.3 ± 0.7
Gila woodpecker *Melanerpes uropygialis*	6.7 ± 1.0	0.7 ± 0.3	0.3 ± 0.3	1.0 ± 0.5	4.3 ± 1.0	0.7 ± 0.5	5.0 ± 0.8
Ladder-backed woodpecker *Picoides scalaris*	1.0 ± 0.5	1.0 ± 0.8		1.3 ± 0.5	0.7 ± 0.2		

Table 6—continued.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East of Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
Unknown woodpecker		0.3 ± 0.3					
Northern flicker *Colaptes auratus*	1.3 ± 0.7	1.3 ± 0.3	1.0 ± 0.0	2.7 ± 0.5	0.7 ± 0.5		1.7 ± 0.5
Empidonax flycatcher *Empidonax* spp.	2.0 ± 0.5	5.7 ± 0.7			4.0 ± 0.5		
Myiarchus flycatcher *Myiarchus* spp.	3.3 ± 0.7	3.3 ± 0.3	0.7 ± 0.5	2.3 ± 0.7	4.3 ± 1.5	1.3 ± 0.3	3.0 ± 0.0
Unknown flycatcher	0.3 ± 0.3						
Violet-green swallow *Tachycineta thalassina*	2.7 ± 0.3		0.3 ± 0.3				
Unknown swallow						0.3 ± 0.3	
Common raven *Corvus corax*			0.7 ± 0.5	0.3 ± 0.3			
Verdin *Auriparus flaviceps*	11.3 ± 1.5	6.0 ± 0.8	0.7 ± 0.5	5.7 ± 0.3	8.3 ± 0.7		5.7 ± 0.7
Cactus wren *Campylorhynchus brunneicappillus*		1.0 ± 0.8	3.7 ± 0.7	2.3 ± 0.3	0.3 ± 0.3		7.0 ± 0.8
Canyon wren *Catherpes mexicanus*		0.3 ± 0.3					
Black-tailed gnatcatcher *Polioptila melanura*	9.3 ± 1.9	3.7 ± 0.5	1.7 ± 0.3	2.3 ± 0.3	5.7 ± 1.1	1.3 ± 0.7	4.6 ± 0.7
Hermit thrush *Catharus guttatus*					0.3 ± 0.3		
Northern mockingbird *Mimus polyglottos*	0.3 ± 0.3	0.3 ± 0.3					

Table 6—continued.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East of Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
Curve-billed thrasher *Toxostoma curvirostre*	2.0 ± 0.5	1.3 ± 0.7	0.3 ± 0.3	1.7 ± 0.7	1.3 ± 1.1		3.3 0.5
Phainopepla *Phainopepla nitens*	13.0 ± 3.3	21.0 ± 2.4	1.3 ± 0.5		19.0 ± 4.5	2.0 ± 1.6	
Loggerhead shrike *Lanius ludovicianus*				0.7 ± 0.3			
Bell's vireo *Vireo bellii*	4.7 ± 0.7				3.3 ± 0.7		
Warbling vireo *Vireo gilvus*	1.0 ± 0.8						
Black-throated gray warbler *Dendroica nigrescens*		0.3 ± 0.3					
Hermit warbler *Dendroica occidentalis*	0.7 ± 0.5						
Townsend's warbler *Dendroica townsendi*	0.3 ± 0.3	3.3 ± 2.7			1.0 ± 0.5	0.3 ± 0.3	
Lucy's warbler *Vermivora luciae*	5.3 ± 0.5		0.3 ± 0.3	0.3 ± 0.3	5.0 ± 0.0		
Wilson's warbler *Wilsonia pusilla*	4.3 ± 0.5	2.0 ± 0.8			3.3 ± 2.3		
Unknown warbler?	1.7 ± 0.7	0.7 ± 0.5					
Western tanager *Piranga ludoviciana*	0.7 ± 0.5	2.3 ± 1.1			0.7 ± 0.3		
Northern cardinal *Cardinalis cardinalis*	2.3 ± 0.3	3.0 ± 0.9			1.0 ± 0.5		0.3 ± 0.3

Table 6—continued.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East of Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
Pyrrhuloxia *Cardinalis sinuatus*					1.0 ± 0.5		
Black-headed grosbeak *Pheucticus melanocephalus*		0.7 ± 0.5			0.3 ± 0.3		
Lazuli bunting *Passerina amoena*		0.3 ± 0.3			0.7 ± 0.5		
Canyon towhee *Pipilo fuscus*	1.3 ± 0.7	3.0 ± 1.2			5.0 ± 1.7		0.3 ± 0.3
Brewers sparrow *Spizella breweri*			10.0 ± 8.2	8.0 ± 6.5			
Black-throated sparrow *Amphispiza bilineata*	0.7 ± 0.5			1.7 ± 0.7	0.7 ± 0.5	2.0 ± 0.8	
White-crowned sparrow *Zonotrichia leucophrys*	1.3 ± 0.7		3.3 ± 2.7				
Yellow-headed blackbird *Xanthocephalus xanthocephalus*			0.3 ± 0.3				
Unknown blackbird			2.0 ± 1.3				
Great-tailed grackle *Quiscalus mexicanus*	1.3 ± 1.1						
Cowbird *Molothrus* spp.	7.7 ± 0.7	3.7 ± 0.5		1.0 ± 0.8	10.0 ± 3.3	0.3 ± 0.3	7.0 ± 2.5
Hooded oriole *Icterus cucullatus*	0.3 ± 0.3	0.7 ± 0.3	0.3 ± 0.3	1.0 ± 0.5	6.7 ± 0.3		0.7 ± 0.5
Scott's oriole *Icterus parisorum*		0.3 ± 0.3		1.3 ± 0.5			1.0 ± 0.5
Unknown oriole							0.3 ± 0.3

Table 6—continued.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East of Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
House finch *Carpodacus mexicanus*	12.3 ± 4.0	12.3 ± 3.5	2.0 ± 0.9	6.3 ± 2.0	1.3 ± 0.5	1.0 ± 0.8	7.7 ± 0.5
Lesser goldfinch *Carduelis psaltria*		2.7 ± 1.4					
Average species richness value	25	20.67	11.33	13.67	23.33	5.67	13.33
Average number of individuals	135	94.67	46.67	44	129.33	11.67	59
Average diversity value (H')	2.841	2.619	2.077	2.353	2.756	1.593	2.412

Desert Pupfish

Introduction

Quitobaquito pond and springs are located in the southwestern portion of ORPI, adjacent to the U.S./Mexico border. An endemic subspecies of the endangered desert pupfish *(Cyprinodon macularius eremus)* inhabits the spring outflows and the pond at Quitobaquito. The water for the pond is provided by 2 springs north of the pond.

The goals of the NPS are to ensure the continued survival and well-being of the endangered desert pupfish, to provide shallow-water habitat for young Sonoran mud turtles (*Kinosternon sonoriense longifemorale*) and to provide a varied habitat for aquatic crustaceans and microorganisms. To this end, the pond, channel, springs and the associated riparian and xeroriparian habitat of the area are inspected weekly. In addition, a census of the pupfish is performed each year.

There are 2 primary objectives of the annual census. The first objective is to provide information on the status of the desert pupfish population present in the Quitobaquito pond and channel. This information includes an estimate of the population size and the distribution of size classes. The second objective is to thoroughly inspect the pond and channel for the presence of nonnative fishes that may detrimentally affect the pupfish population. Accomplishment of both objectives provides a preliminary basis for the evaluation of the health of the pupfish population at Quitobaquito. Further research, monitoring, and management actions are recommended based on census results.

Project History

Pupfish Census

Pupfish census work began at Quitobaquito with research conducted by Boyd E. Kynard (The University of Arizona) in 1975 and continued almost yearly through 1981. Population estimates ranged from a high of 7,294 individuals in 1975 to a low of 1,800 in 1981, with intervening years showing a range of 3,000 to 6,700 individuals. The reliability of these figures has always been in question and resulted in contract research with The University of Arizona in 1985 to determine the most suitable method for sampling this species.

Prior to 1985, left pectoral fins were clipped on fish ≥ 22 mm long and population size estimated using mark-recapture. This involved considerable handling of each individual. In 1985, Bill Matter (The University of Arizona) assisted the park in developing a census technique that bases the population estimates on depletion of the population from several successive trapping efforts. Fish from each trapping effort were temporarily held in a screened holding tank which was maintained in the pond. The total catch per "trapping run" was plotted against the accumulated catch to arrive at an estimate of the total population. This method has been of limited success in that there has not been consistent depletion, partially due to the limited number of trapping runs.

Based on observations during each census, this and other methods provided estimates of the population that were probably low.

Quitobaquito Habitat Project

In November 1989, the Quitobaquito Habitat Project, developed in consultation with the U.S. Fish and Wildlife Service, was initiated. The project was designed to provide a natural-appearing shallow-water habitat for desert pupfish, young Sonoran mud turtles, and associated crustaceans and microorganisms. The goal of the Quitobaquito Habitat Project was to enhance the present habitat of the desert pupfish and associated fauna, particularly the Sonoran mud turtle, and to reduce or eliminate catastrophic events such as have occurred twice in recent history, when the pond water level fell significantly enough to threaten pupfish habitat. Because of rapid vegetation growth in the open earthen ditches and pools associated with the 2 springs feeding the pond, the system that holds and transports water was designed to be as maintenance-free as possible. Although wetland vegetation still proliferates quickly in the channel and must be periodically removed, the new system is physically more stable than the old ditches and guarantees constant water delivery to the pond and habitat for aquatic vertebrates and invertebrates.

The project consisted of constructing an open concrete-lined stream channel from the springs to the pond, with an underground pipeline backup. The channel is the primary means of water transport from the springs to the pond. The stream channel was designed to duplicate the approximate width and depth historically used when the area was farmed, and incorporates areas of both slower and faster moving water. The use of pools, overhangs and islands within the stream channel provide protection and necessary habitat for both desert pupfish and Sonoran mud turtles.

The project was completed in December 1989. Four years of monitoring of the pond and channel have revealed encouraging data. Within 1 week after the channel to the pond was opened, pupfish were found at the southwest spring, an indication that they had moved up the entire length of the 213-m channel. As of the writing of this report, desert pupfish have now fully colonized the entire length of the new channel, and are found primarily in the shallow pools.

1994 Monitoring Activities

Weekly Inspections of Quitobaquito

The Quitobaquito area was inspected once a week throughout 1994 by ORPI resource management staff. Inspections involved visually inspecting the channel, the southwest and northeast springs, pond perimeter, pond outflow, trails and the historic fig and pomegranate orchard. Emphasis on observations of pupfish included visually monitoring for presence along the stream channel, springs, and pond perimeter. Notes were made of habitat use, areas of concentration and age classes. Observation for the presence of nonnative fishes such as mosquitofish *(Gambusia affinis)* and catfish *(Ictalurus melas)* is also of primary importance.

Annual Quitobaquito Desert Pupfish Census

On 26–27 September 1994, monument staff conducted pupfish censuses at Quitobaquito pond and channel under U.S. Fish and Wildlife Service Endangered Species Subpermit PRT-676811.

Although in 1993 a spring census was also conducted, it was dropped in 1994 to avoid unnecessary impact.

Methods for the Pupfish Census

Quitobaquito Pond

The 1994 census of Quitobaquito pond was conducted using 47 traps placed around the perimeter of the pond. The traps contained no bait, and a trapping run consisted of a 2-hour period after which the trap was emptied into an ice chest in the boat and placed back in the pond, except at day's end. Three runs were done each day for a total of 6 runs over the 2-day period. The fish from each run were counted, and approximately 65 randomly selected fish from each run were measured for length, to determine size distribution. The fish were then placed in a holding tank outside the pond, aerated continuously. Once trapped, the fish were held until the end of the census, for a total of about 28 hours of captivity for the fish trapped during the first run.

Quitobaquito Channel

The 1994 census of the Quitobaquito channel and springs was done using 10 traps placed in the spring channel and 2 traps placed at the southwest spring. One run of approximately 4 hours was done each day of the census. The fish from the runs in the channel and spring were counted and released, with 15 fish being measured for length from each trap that held at least 15 fish. All fish were measured from each trap that held 15 or fewer fish. A total of 15 fish were measured from the 2 traps at the southwest spring. Fish that were trapped in the channel and spring were not held, due to the potential for harm in the transport of the fish to the holding tank.

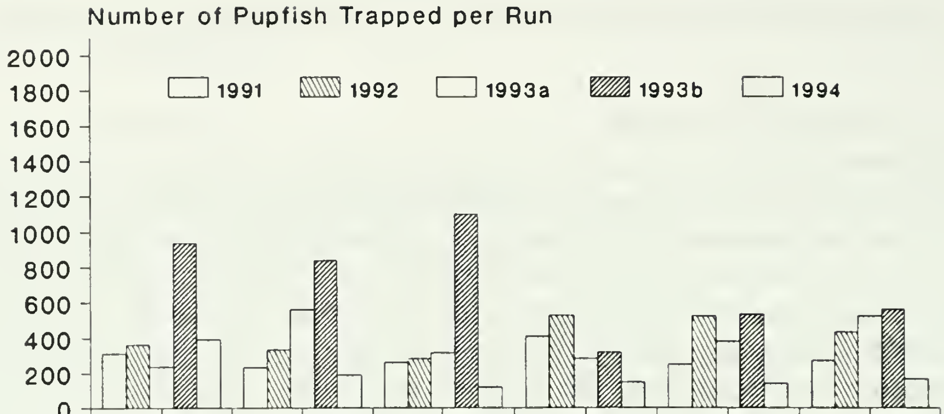
Results

Pupfish Census

A total of 2,327 pupfish were trapped in 1994 in the channel and pond. Of these, 1,165 were trapped in the channel. This is similar to the number trapped in the channel in the spring and summer censuses of 1993, which yielded 1,128 and 1,160, respectively. The number trapped in 1994 is also similar to the 1992 number of 1,136. However, the number of pupfish trapped in the pond in 1994 (1,162) was below that of previous censuses. On the 1992 summer census, 2,470 pupfish were trapped, 2,305 and 4,299 for the 1993 spring and summer censuses, respectively (Fig. 54). No nonnative fishes were captured or observed in either the pond or channel. Total mortality for the 2-day trapping period was 11 pupfish. Pupfish size distribution for 1994 is summarized in Figure 55.

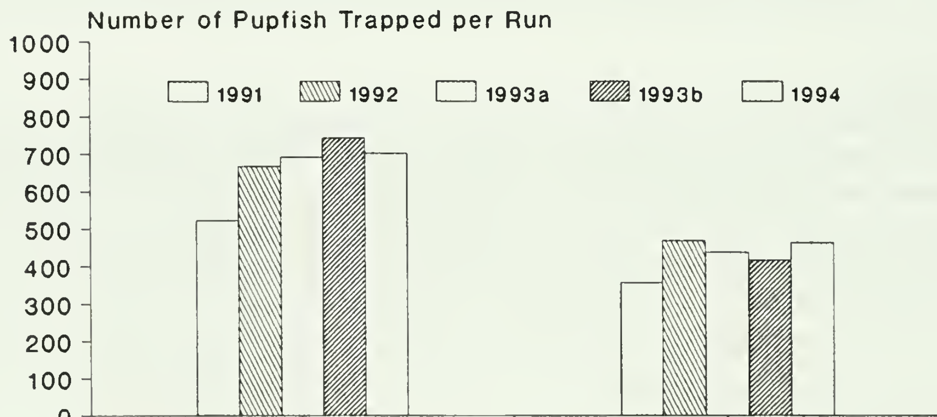
The fairly consistent number of pupfish trapped in the channel in recent censuses may be a positive indication of the stability of the population. However, because the number trapped in the channel would be expected to include recaptures from the first day (the fish trapped the first day were released), these numbers are difficult to interpret. The fact that fewer pupfish were trapped in the pond in 1994 than in 1992 and 1993 (roughly 25–50% fewer) indicates the need for continued monitoring.

Quitobaquito Pond



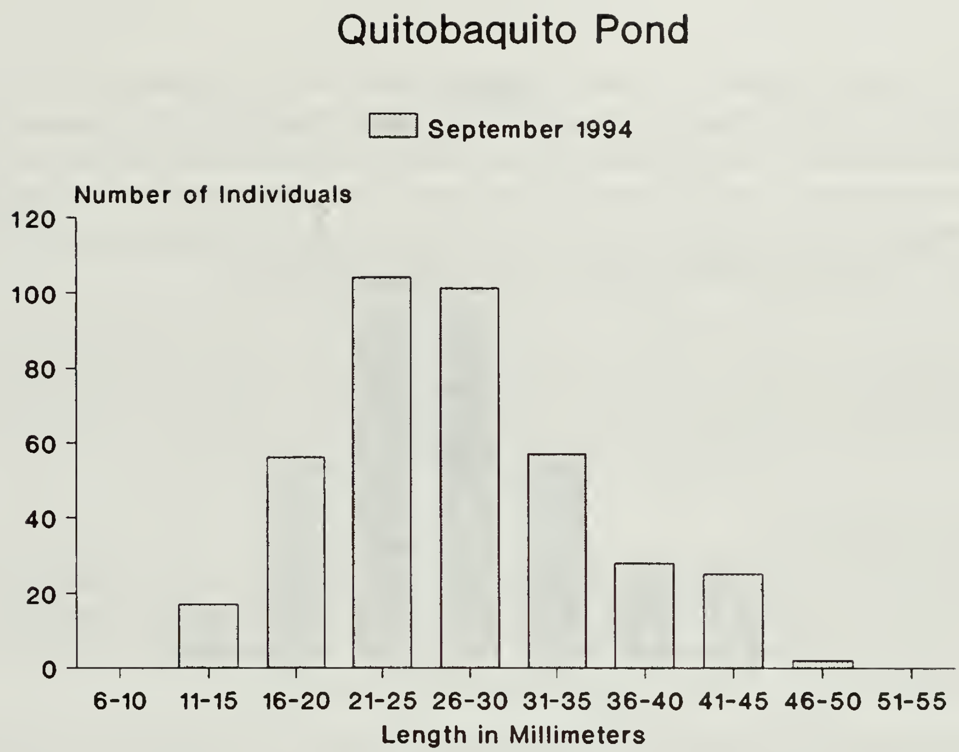
	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
1991	311	233	260	411	250	273
1992	362	335	284	528	525	436
1993a	238	563	316	283	381	524
1993b	936	840	1101	320	538	564
1994	392	191	119	149	143	168

Quitobaquito Channel



	RUN 1	RUN 2
1991	522	357
1992	667	469
1993a	690	438
1993b	743	417
1994	701	464

Figure 54. Number of pupfish *(Cyprinodon macularius eremus)* trapped per run in Quitobaquito channel and pond, Organ Pipe Cactus National Monument, Arizona, 1991–1994.



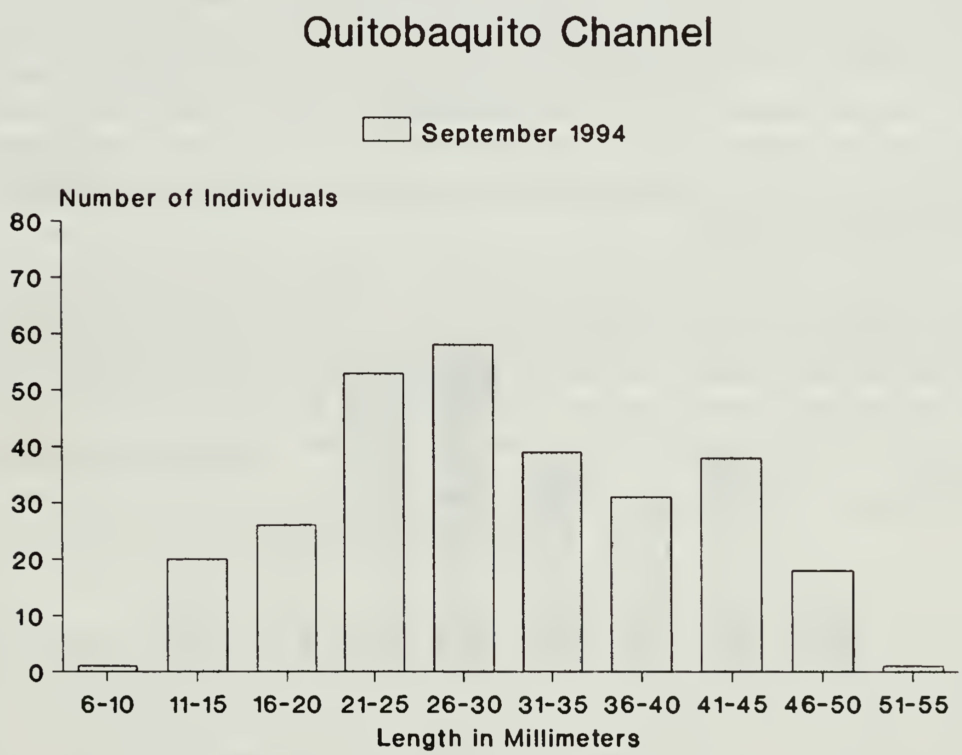


Figure 55. Size distribution of pupfish *(Cyprinodon macularius eremus)* caught in Quitobaquito channel and pond, Organ Pipe Cactus National Monument, Arizona, during the 1994 census.

The vegetation in and alongside the channel seems to have grown to its maximum and is now fairly stable, although still subject to seasonal variation and maintenance by monument staff. This vegetation provides cover and habitat for both fish and turtles, and the aquatic vegetation and bulrush root masses are cleared minimally to maintain an open channel and unimpaired water flow. Pupfish exist in large numbers in both pond and channel habitats, even when pools become thickly vegetated with both aquatic and terrestrial vegetation.

Based on visual observations during the census, the fish that were caught appear to be a fraction of the total pupfish population in the pond and channel. There appears to be a healthy distribution of age/size classes, and no nonnative fish species or other exotic competitors were observed. All indications are that the present population of pupfishes is in good condition.

Quitobaquito Inspections

On a weekly inspection in October 1994, vandalism was discovered at the northeast spring. The spring cover had been forcibly removed and the outflow valve turned off, causing the springbox to fill and overflow. Although water delivery to the channel was subsequently decreased and the pond level dropped several inches, no pupfish mortality was observed.

The rest of the 1994 weekly inspections and maintenance of the pond and channel went without any major incidents, with the main task that of clearing various parts of the channel of aquatic vegetation and root masses. This clearing was done in a gradual and minimal way so as to reduce impact while keeping the water flowing. Once again it was observed that pupfish appeared in large numbers in all parts of pools where aquatic vegetation (usually root masses) had been cleared back to the pool edges. This was true throughout the length of the channel, from the southwest spring to the channel mouth. In the future, the pools will be better maintained in a partially cleared state, while not disturbing the pool perimeters or substrate. No nonnative fishes were observed during inspections.

Another aspect of the Quitobaquito inspection process is natural history observations. Plants in bloom, wildlife, and other noteworthy observations are recorded. In 1994, approximately 7 Sonoran mud turtles were observed in channel and pond. The hot, dry summer of 1994 also caused increased wildlife visitation to the Quitobaquito area. Mule deer were often sighted, and trampling at the pond and channel banks was very evident. Two mule deer carcasses were found near the channel.

Bats

Introduction

Bats comprise the second largest group of mammals in the world but their mobility, nocturnal habits, and secretive or inaccessible roost sites make it difficult to study their numbers and diversity. Fourteen species of bats are known to occur in ORPI, including a large maternal colony of the endangered lesser long-nosed bat *(Leptonycteris curasoae)* and federally listed category 2 species, the California leaf-nosed bat *(Macrotus californicus)*, Underwood's mastiff bat *(Eumops underwoodi)*, the western mastiff bat *(Eumops perotis californicus)*, the cave myotis *(Myotis velifer)*, and Townsend's big-eared bat *(Plecotus townsendii pallescens)*. E. Lendell Cockrum (1981) summarized bat populations, life histories, and habitats at ORPI. Since that time, elimination of cattle grazing and closing of abandoned mines may have affected historic water sources and roost sites. In 1993, Yar Petryszyn was contracted to assess the current abundance and diversity of this important mammal group in the monument and to develop a long-term monitoring protocol.

Locating bat day roosts and performing exit counts is a difficult method of bat monitoring. Since all insect-eating bats must drink water every day, annual mist-netting at water holes during the summer months can provide a long-term database of bat activity. Although mist-netting is dependent on weather and the differing success of capturing bat species, it provides one of the only methods of determining diversity and relative abundance of bats in a specific area. Over time, gross changes in diversity and numbers may become apparent.

Project History

In 1993, principal investigator Petryszyn visited the monument to gather baseline information on bat diversity and develop a long-term monitoring protocol. Tinajas, springs, and Quitobaquito pond were chosen for mist-net sampling. Since bats are creatures of habit, tinajas with the most capacity for water in the hottest part of the year were chosen to capture the highest concentration of bats. In addition, Quitobaquito pond was mist-netted bimonthly in 1993, 1994, and 1995 by Petryszyn for a study on Underwood's mastiff bat.

1994 Monitoring Activities

Resource management staff conducted bat monitoring on 4–8 June 1994. The same 5 sites chosen by Petryszyn in 1993 were sampled in 1994.

Methods

Mist nets are made of a very fine black mesh that bats usually cannot detect with echolocation until too late to avoid becoming entangled. Netting was performed at tinaja sites with 18-ft or 30-ft length mist nets placed at the edge of a pool or in a flyway near a pool. At Quitobaquito, a boat was used to set up a 120-ft net across the middle of the pond. Nets were opened at dusk and closed at midnight. Nets were checked regularly for bat capture. Bats were removed from the net and released after species, sex, age, and reproductive condition were determined.

Results

Data from 1993 and 1994 monitoring sessions are summarized in tables. Female reproductive status is summarized in the categories of "lactating," "post-lactating," and "non-reproductive." Pregnant females were placed in the "lactating" category.

The late summer 1993 mist netting generally yielded a higher density and a different age structure than the June 1994 monitoring. After monsoon rains in 1993, a higher level of foraging activity might explain higher density. Juvenile bats are also more numerous in the late summer.

The endangered lesser long-nosed bat was netted more frequently than expected at the tinajas. This nectar and fruit-eating species is not generally believed to need supplemental water, yet was caught next to tinajas without a natural flyway that could explain their presence and was at times observed flying to water. Another nectar-feeding species, the Mexican long-tongued bat *(Choeronycteris mexicana)*, was caught in 1994, the first verified record for ORPI.

Detailed site results are summarized as follows:

North Fork Alamo Canyon (Table 7)

Approximately 0.8 km upstream of the confluence of North and South forks of Alamo Canyon in the Ajo Mountains, nets were set at a tinaja with capacity to hold water in the hottest time of the year. One 18-ft net was set across a small pool and one 30-ft net was set slightly downstream over another water area. For the initial 1993 project, bats were netted for 2 nights and marked with temporary white paint. No significant amount of recapture was recorded either the first night or the second night, so marking was determined to be of little value in future monitoring. The western pipistrelle *(Pipistrellus hesperus)* and lesser long-nosed bat were the most numerous species in 1993 and 1994.

Wild Horse Tank (Table 8)

This Diablo Mountains water source is a semi-permanent pool below a cliff with an artificial dam built in historic ranching days. One 30-ft net was placed at the edge of the pool. Both bat diversity and abundance are high at this site. During the 1993 baseline data gathering, Wild Horse Tank was visited both in August and September. A species normally found only in higher elevations, Townsend's big-eared bat was caught here in September 1993.

Bull Pasture (Table 9)

Several deep tinajas are found in this lush middle elevation area of the Ajo Mountains. Sampling was conducted at tinajas in a drainage that pours into a large canyon. In 1993, a 30-ft net and a 18-ft net were placed over the water pools in this narrow drainage. A high rate of capture forced field workers to close the downstream net, and it was not placed in 1994. Also in 1993, the nets were closed at 10 p.m. because the current U.S. Fish and Wildlife Service permit limit of 5 lesser long-nosed bats captured was exceeded. (The capture limit was subsequently increased to 40.) Western pipistrelle, cave myotis, and lesser long-nosed bat were the most abundant bats at this site.

Table 7. Bat monitoring at North Fork Alamo Canyon Tinajas, Organ Pipe Cactus National Monument, Arizona, 1993–1994. On 6 August, 2, 18-ft mist nets were placed over water sources and one 30-ft net was placed below those water sources in a flyway in the canyon. Subsequent monitoring in this area utilized only 1, 18-ft net and the 30-ft flyway net.

North Fork Alamo Canyon, 6 August 1993

Species	Adult male	Lactating female	Post-Lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	6	0	0	11	3	7	27
Myotis velifer	0	0	0	1	0	1	2
Myotis californicus	0	0	0	0	0	0	0
Eptesicus fuscus	0	0	1	1	0	0	2
Macrotus californicus	1	0	0	2	0	0	3
Leptonycteris curasoae	0	0	0	2	2	0	4
Choeronycteris mexicana	0	0	0	0	0	0	0
Antrozous pallidus	1	0	0	1	0	0	2
Total	8	0	1	18	5	8	40

North Fork Alamo Canyon, 7 August 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	8	0	0	15	8	6	37
Myotis velifer	0	0	0	0	0	0	0
Myotis californicus	1	0	0	0	0	0	1
Eptesicus fuscus	1	0	0	1	0	0	2
Macrotus californicus	0	0	1	2	0	0	3
Leptonycteris curasoae	0	0	0	2	4	3	9
Choeronycteris mexicana	0	0	0	0	0	0	0
Antrozous pallidus	4	0	0	2	0	0	6
Total	14	0	1	22	12	9	58

Table 7—continued.

North Fork Alamo Canyon, 5 June 1994							
Species	Adult male	Lactating female	Post-Lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	3	1	0	1	0	0	5
Myotis velifer	0	0	0	0	0	0	0
Myotis californicus	0	1	0	0	0	0	1
Eptesicus fuscus	1	0	0	0	0	0	1
Macrotus californicus	0	0	0	0	0	0	0
Leptonycteris curasoae	0	6	0	2	0	0	8
Choeronycteris mexicana	0	1	0	0	0	0	1
Antrozous pallidus	2	0	0	0	0	0	2
Total	6	9	0	3	0	0	18

Table 8. Bat monitoring at Wild Horse Tank, Organ Pipe Cactus National Monument, Arizona, 1993–1994. One 30-ft net was placed at the edge of the pool.

Wild Horse Tank, 9 August 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	19	0	0	14	13	10	56
Myotis velifer	2	0	0	2	1	0	5
Myotis californicus	2	0	0	0	0	0	2
Eptesicus fuscus	1	0	0	1	0	0	2
Macrotus californicus	1	0	0	2	0	1	4
Leptonycteris curasoae	0	0	0	2	4	6	12
Antrozous pallidus	3	0	0	1	0	0	4
Total	28	0	0	22	18	17	85

Wild Horse Tank, 9 September 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	13	0	0	7	0	0	20
Myotis velifer	0	0	0	0	0	0	0
Myotis californicus	0	0	0	0	0	0	0
Eptesicus fuscus	3	0	0	0	0	0	3
Macrotus californicus	0	0	0	0	0	0	0
Leptonycteris curasoae	0	0	0	0	0	0	0
Plecotus townsendii	1	0	0	0	0	0	1
Antrozous pallidus	6	0	0	0	0	0	6
Total	23	0	0	7	0	0	30

Table 8—continued.

Wild Horse Tank, 4 June 1994

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	33	0	0	2	0	0	35
Myotis velifer	2	0	0	12	0	0	14
Myotis californicus	0	0	0	4	0	0	4
Eptesicus fuscus	1	0	0	0	0	0	1
Macrotus californicus	1	0	0	1	0	0	2
Leptonycteris curasoae	0	1	0	2	0	0	3
Antrozous pallidus	0	0	0	0	0	0	0
Total	37	1	0	21	0	0	59

Table 9. Bat monitoring at Bull Pasture Tinajas, Organ Pipe Cactus National Monument, Arizona, 1993–1994. In 1993, 1, 30-ft mist net and 1, 18-ft mist net were placed over tinaja pools. Monitoring was stopped at 10 p.m. because of exceedance of current U.S. Fish and Wildlife Service permit for capture of lesser long-nosed bat *(Leptonyctoris curasoae)*. In 1994, only one 18-ft net was used for monitoring.

Bull Pasture, 8 August 1993

Species	Adult male	Lactating female	Post-Lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	9	0	0	9	1	1	20
Myotis velifer	6	0	0	3	2	0	11
Myotis californicus	0	0	0	0	0	0	0
Eptesicus fuscus	0	0	1	0	0	0	1
Macrotus californicus	0	0	0	0	0	0	0
Leptonycteris curasoae	0	0	2	0	8	8	18
Antrozous pallidus	2	0	0	0	0	0	2
Total	17	0	3	12	11	9	52

Bull Pasture, 6 June 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	1	0	0	0	0	0	1
Myotis velifer	1	0	0	1	0	0	2
Myotis californicus	0	0	0	0	0	0	0
Eptesicus fuscus	0	0	0	0	0	0	0
Macrotus californicus	0	0	0	0	0	0	0
Leptonycteris curasoae	0	12	0	6	0	0	18
Antrozous pallidus	0	0	0	0	0	0	0
Total	2	12	0	7	0	0	21

Bates Valley Tinajas (Table 10)

The Bates Mountain Range in the northwestern corner of the monument contains 2 principal tinaja sites, Tinajas Estufas and Hidden Gorge Tinajas. In 1993, Tinajas Estufas were sampled for 2 nights with 2, 18-ft nets next to pools. Bat diversity was high at this site although density was low. The big brown bat (*Eptesicus fuscus*) and western pipistrelle were the most common bats in 1993. In June 1994, the Tinajas Estufas were completely dry. The nearby Hidden Gorge plunge pool tinajas were mostly dry as well, except for 1 small 1-ft wide pool below a steep cliff. An 18-ft net was placed in the flyway above this pool. Many bats were observed visiting the pool during the night, but very few were caught.

Dripping Springs (Table 11)

This permanent water pool in a rock overhang on a mountainous slope in the Puerto Blanco Mountains is difficult to sample because of dense shrubby vegetation growth around the pool. An 18-ft net was placed across the overhang opening. Western pipistrelle,big brown bat, and the pallid bat *(Antrozous pallidus)* were among the bats caught here. In 1994, lesser long-nosed bat was also caught at this obscure water location.

Quitobaquito (Table 12)

The 120-ft net was set up and checked by boat at this spring-fed pond approximately 0.22 ha in size. Because of the rare source of open water in the area, bats of the Molossidae family are found here. Characteristics of this family—narrow wings and a "free" tail—cause a relative lack of mobility and need for a large water source to drink nightly. The pocketed free-tailed bat *(Nyctinomops femorosaccus)* and one of the largest bats in North America, Underwood's mastiff bat, were caught here in 1993 and 1994. The first confirmed record of another species of free-tailed bat, the Mexican free-tailed bat (*Tadarida brasiliensis*), was made here in 1993. This species passes through the monument during its spring and fall migrations.

Overall poor results in September 1993 were due to a bright moon and stong breezes, which limit bat activity and cause the mist net to become more visible to bats. The sampling in 1994 was part of Petryszyn's year-long research project on *Eumops*, and during this project the net remained open until dawn.

Table 10. Bat monitoring in the Bates Valley, Organ Pipe Cactus, Arizona, 1993–1994. Data from 1993 are from the Tinajas Estufa where 2, 18-ft nets were used. These tinajas were dry in June 1994, so a flyway in the nearby Hidden Gorge Tinaja was sampled with one 18-ft net.

Tinaja Estufa, 6 September 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	4	0	0	2	0	0	6
Myotis velifer	0	0	0	1	0	0	1
Myotis californicus	0	0	0	2	0	0	2
Eptesicus fuscus	1	0	0	2	0	0	3
Macrotus californicus	0	0	0	1	0	0	1
Leptonycteris curasoae	0	0	0	1	0	0	1
Antrozous pallidus	0	0	0	0	0	0	0
Total	5	0	0	9	0	0	14

Tinaja Estufa, 7 September 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	2	0	2	5	1	1	11
Myotis velifer	0	0	0	0	0	0	0
Myotis californicus	0	0	0	0	0	0	0
Eptesicus fuscus	2	0	1	3	0	0	6
Macrotus californicus	0	0	2	2	0	0	4
Leptonycteris curasoae	0	0	0	1	0	0	1
Antrozous pallidus	1	0	1	1	0	0	3
Total	5	0	6	12	1	1	25

Table 10—continued.

Hidden Gorge Tinajas, 8 June 1994							
Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	0	0	0	0	0	0	0
Myotis velifer	0	0	0	0	0	0	0
Myotis californicus	0	0	0	0	0	0	0
Eptesicus fuscus	0	0	0	0	0	0	0
Macrotus californicus	4	0	0	0	0	0	4
Leptonycteris curasoae	0	0	0	1	0	0	1
Antrozous pallidus	1	0	0	0	0	0	1
Total	5	0	0	1	0	0	6

Table 11. Bat monitoring at Dripping Springs, Organ Pipe Cactus National Monument, Arizona, 1993–1994. One 18-ft net was stretched in front of the rock overhang where a permanent pool of dripping water is located.

Dripping Springs, 9 September 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	1	0	0	3	0	0	4
Myotis velifer	0	0	0	1	0	0	1
Myotis californicus	0	0	0	0	0	0	0
Eptesicus fuscus	1	0	0	1	0	0	2
Macrotus californicus	0	0	0	0	0	0	0
Leptonycteris curasoae	0	0	0	0	0	0	0
Antrozous pallidus	5	0	0	0	0	0	5
Total	7	0	0	5	0	0	12

Dripping Springs, 7 June 1994

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	8	0	0	2	0	0	10
Myotis velifer	0	1	0	1	0	0	2
Myotis californicus	0	0	0	0	0	0	0
Eptesicus fuscus	3	2	0	2	0	0	7
Macrotus californicus	0	0	0	0	0	0	0
Leptonycteris curasoae	0	2	0	0	0	0	2
Antrozous pallidus	1	0	0	0	0	0	1
Total	12	5	0	5	0	0	22

Table 12. Bat monitoring at Quitobaquito Pond, Organ Pipe Cactus National Monument, 1993–1994. One 120-ft net is used in monitoring at Quitobaquito Pond. On 2–3 June 1994, the mist net was left open until dawn instead of the usual midnight closing time.

Quitobaquito Pond, 22 September 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	0	0	0	1	0	0	1
Tadarida femorosaccus	2	0	0	7	0	0	9
Tadarida brasiliensis	1	0	0	0	0	0	1
Total	3	0	0	8	0	0	11

Quitobaquito Pond, 23 September 1993

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	0	0	0	0	0	0	0
Tadarida femorosaccus	0	0	0	1	0	0	1
Tadarida brasiliensis	0	0	0	0	0	0	0
Total	0	0	0	1	0	0	1

Quitobaquito Pond, 2 June 1994

Species	Adult Male	Lactating Female	Post-Lact. Female	Female, No repro.	Juvenile Male	Juvenile Female	Total
Pipistrellus hesperus	1	1	0	0	0	0	2
Eptesicus fuscus	1	0	0	0	0	0	1
Tadarida femorosaccus	39	1	0	15	0	0	55
Eumops underwoodi	2	1	0	9	0	0	12
Total	43	3	0	24	0	0	70

Table 12—continued.

Quitobaquito Pond, 3 June 1994

Species	Adult male	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	0	0	0	0	0	0	0
Eptesicus fuscus	0	0	0	2	0	0	2
Tadarida femorosaccus	17	0	0	13	0	0	30
Eumops underwoodi	4	0	0	2	0	0	6
Total	21	0	0	17	0	0	

Lesser Long-nosed Bat

Introduction

The lesser long-nosed bat (*Leptonycteris curasoae*) is a nectar, pollen, and fruit-eating bat that migrates seasonally from Mexico to southern Arizona and southwestern New Mexico. This species was designated federally endangered by the U.S. Fish and Wildlife Service in 1988, because surveys in Arizona and Mexico conducted from the 1970s to 1985 failed to reveal large numbers of this bat. A draft recovery plan has been issued by the U.S. Fish and Wildlife Service. This plan provides for the de-listing of the lesser long-nosed bat as a federally endangered species after 5 years if maternity roosts in Arizona and Mexico show no decline in numbers.

Organ Pipe Cactus National Monument is home to the largest known maternity colony of lesser long-nosed bats in Arizona. Copper Mountain, an abandoned adit in the northeast portion of the monument, houses 10,000–20,000 female bats with young between April and November. During this period, the bats play an important role in the pollination of agaves *(Agave* spp.*)* and organ pipe *(Lemaireocereus thurberi),* senita *(Lophocereus schotti)* and saguaro cacti *(Carnegiea gigantea),* as well as seed dispersal. Since many aspects of lesser long-nosed bat ecology are still unknown, the monument plays an important role in the protection of a vital maternal roost, as well as with coordination of research and monitoring efforts. The principal function of the resource management staff has been to assist researchers in conducting specific lesser long-nosed bat projects and to help with census events, field observations of behavior and remote-sensing equipment maintenance.

Project History

The Copper Mountain maternity colony was discovered in 1989. During the spring, summer, and fall of 1989 through 1993, exit counts were conducted at the mine. Four methods (or combinations thereof) were used, including live monitoring with dim white or red light, night-vision live viewing, night vision videotaping, and walk-through checks. In early spring and early fall, the mine was checked to see when the bats arrived and left for the season. Temperature and humidity were continuously recorded at various locations within the mine at hourly intervals throughout the year, from March 1990 to the present.

An NPS-funded research project was conducted in 1993 to evaluate the status of bat populations at ORPI. The component of this study, to evaluate and assess the status of the Copper Mountain lesser long-nosed bat maternity colony, was conducted by Virginia and David Dalton. The Daltons conducted past population estimates and established the current remote sensing program. They were also the principal investigators in the evaluation of the effects of low-level military aircraft on the colony in 1992.

1994 Monitoring Activities

Monitoring efforts in 1994 included maintenance of a remote monitoring system to gather baseline data on roost temperature, humidity, and sound levels. Flight counts were not continued in 1994. However, guano samples were collected regularly throughout the period of use by bats,

both during and after the primary food sources were in bloom or bearing fruit. Guano splatter sheets were placed in the mine tunnel and replaced approximately every other week. Samples were scraped from these sheets and frozen for later analysis. A report on this analysis was received from Peter Van de Water in February 1994.

A component of a U.S. Air Force Legacy Fund study on the foraging ecology of lesser long-nosed bat in the Sand Tank Mountains (Barry M. Goldwater Gunnery Range) took place in the monument. On 29 May 1994, 100 bats were captured at Copper Mountain and fitted with light tags. Observers were then stationed on high points in the monument and Sand Tank Mountains to search for light-tagged bats. Principal investigators for this project are the Daltons.

Methods

The Copper Mountain remote sensing system is composed of a series of temperature and humidity probes located throughout the mine tunnel and linked to a computer. Recordings are continuous, and data are downloaded monthly to computers located at monument headquarters.

Guano splatter sheets were placed in the mine tunnel and replaced approximately every other week. To minimize disturbance, the guano sheet replacement was conducted at mid-morning to coincide with the bats' low point of activity. Sheets with samples were then frozen and will be stored until analysis can be performed.

During the Dalton's foraging territory study on 29 May, 100 bats were captured at Copper Mountain in a harp trap, as they exited from their day roost. They were then fitted with light tags—clear glass spheres filled with a luminescent material—which is visible for a great distance. The tags fall off or are groomed off within 24 hours. The Copper Mountain release station was linked by radio to the observer stations. Observers were situated on high points near the release site, at localities distant from the release site and at potential foraging areas. All observations of light-tagged bat activities were recorded.

Results

Lesser long-nosed bats appear to begin arriving at Copper Mountain Mine in small numbers in mid- to late April. They do not seem to arrive simultaneously. There are only some hundreds of animals early and late in the season rather than the usual thousands one sees mid-season. Although no census counts were performed, observations of bat activity in the mine made during guano sheet replacement revealed numbers of bats consistent with previous seasons.

The environmental recording system was installed in 1990 to measure temperature and humidity conditions in the mine roosts. The temperature rises gradually deep inside the mine, correlating with the arrival of bats for the season. Other temperatures in the main passage do not correlate with these events; instead, they fluctuate directly with the ambient outside temperatures. It appears that the bats can alter the roost temperature with their own body heat by as much as 3-4° F. daily. In summer 1994, the recording system quit functioning and the computer was removed. The Resources Management Division is exploring options for a new remote sensing system for Copper Mountain.

Guano analysis made by Peter Van de Water in 1993 showed that the bats utilized pollen from both cacti (*Cereus*-type) and agave species during the summer season. The data in his report will be used in future foraging ecology studies.

Virginia and David Dalton summarized the results of the ORPI phase of their U.S. Air Force Legacy Fund study in a supplement to their 1994 investigator's annual report. They found that the majority of tagged bats foraged from 1 to 6 km from the roost site, in the Valley of the Ajo. This part of the valley appears to be an important foraging area for long-nosed bats early in the season when the young are still dependent upon their mother's milk. Copper Mountain bats probably also forage further away as the season progresses, when the food supply changes from cactus flowers to fruits, and more territory is needed for the weaned young.

Climate

Introduction

Scientists and managers recognized early in monitoring program planning that climate data are an integral part of any attempt to study or to understand environmental changes in an ecosystem. In the Sonoran Desert, plants and animals must adapt to highly variable weather conditions and unpredictable rainfall, and their populations are directly and indirectly influenced by climatic events. Indeed, climate, and especially precipitation, seems to be a powerful "forcing function" in the ecology of the desert. Thus, climate data are the primary integrative component of the EMP. Organ Pipe Cactus National Monument has both automated weather stations and rain gauges in place near monitoring sites and at other locations.

Project History

In 1987, work began on the installation of 9 automated weather stations at sites in the monument designated as ecological monitoring sites. These stations all came "on line" in 1988 and have been providing essentially continuous data. Eight Forester rain gauges are also located throughout the monument. Most of these have been in use since the early 1960s, though not consistently until 1982.

1994 Monitoring Activities

Resource management personnel serviced all 9 automated weather stations monthly in 1994. Servicing consists of changing data storage modules, replacing batteries when necessary, and checking for damaged or malfunctioning equipment. Data were downloaded and entered into Lotus spreadsheets. Rain gauges were checked at the end of each month to determine the monthly total rainfall.

Methods

The configuration of instruments varies from site to site, with each weather station having 2–4 of the following datapod recorders (and associated sensing instruments):

DP-211 Solar radiation and soil temperature at 10 cm
- at Aguajita, Neolloydia, and Senita Basin

DP-214 Wind speed and direction
- at all sites but Gachado and Neolloydia

DP-220 Air temperature and relative humidity at 48 in.
- at all sites but Neolloydia

DP-230 Air temperature at 15 cm and precipitation
- at all sites

All recorders record data at 1-hour intervals, except for the DP-230, which records at 2-hour intervals. A description of the data is given below:

Weather Parameter	Sampling Interval	Type of Sample
Air temperature at 48 in.	10 minutes	instantaneous
Air temperature at 15 cm	5 minutes	average
Soil temperature at 10 cm	5 minutes	average
Relative humidity at 48 in.	10 minutes	instantaneous
Wind speed and direction	3 minutes	average
Solar radiation	5 minutes	average
Precipitation	cumulative	count

Accuracy of the sensor/recorder combinations (as advertised) are:

Temperature	+/- 0.5° C
Relative humidity	+/- 5.0 %
Wind speed	+/- 1.0 mph
Wind direction	+/- 3.0 degrees
Solar radiation	+/- 5.0 %
Precipitation	+/- 0.5 % at 0.5 in. per hour
	+/- 4.0 % at 1 to 6 in. per hour

To maintain the accuracy of the data, it is necessary to check the sensors, which involves periodic verification of temperature and humidity, as well as calibration of the tipping bucket rain gauges. Most of these sensors have a limited life of 1–3 years and some will need to be replaced or recalibrated at the factory within the near future. The relative humidity sensors were all replaced at the end of 1991, with a significant improvement in accuracy, and were replaced again in 1994. The solar radiation sensors are known to have deteriorated and lost accuracy, and should be replaced. The wind speed sensors are beginning to show an increased threshold of starting speed, and some of the wind direction sensors are giving intermittent erroneous readings. These will be checked again and replaced as needed. The temperature sensors are still good.

After data are downloaded, summary spreadsheets are created in Lotus 1-2-3. The summaries give daily means, maximums, minimums, and totals of all measured parameters of each site. Intersite comparisons give daily comparisons among all sites where a given parameter is measured. These summaries, comparisons, and the raw hourly data are available for all 9 weather stations and are stored on floppy disks in a fire-proof vault, and in the office of the chief of resource management.

Monthly rainfall data are gathered from the forester rain gauges by measuring the amount of pre-measured transmission fluid (which prevents evaporation of precipitation) and rain water in the bucket, and subtracting the known quantity of transmission fluid. Then fresh transmission fluid is measured and placed in the bucket. Water is filtered out of the used transmission fluid so that the fluid can be reused. Data from these rain gauges are entered into a Lotus spreadsheet.

Results

In 1994, there was the usual array of technical and environmental difficulties that one would expect of any technological system subject to constant exposure to the elements. Easily, the most serious problem is still the age and wear and tear on the sensing instruments. Temperature readings continue to be quite accurate. Humidity figures are a bit low in the low range, but quite accurate otherwise, now that the sensors have been changed. Wind speed and direction data are suspect at many of the sites. Solar radiation numbers are high. Rainfall data are accurate, although some question exists regarding the basic design of the raingauge: the screen on top that keeps debris out of the small funnel may cause a significant amount of deflection of rain or hail, especially during a downpour. This question needs to be resolved in light of the fact that the average rainfall for the forester raingauges consistently exceeds that for the tipping buckets, even on a similar site comparison.

Six different reports are available summarizing the hourly data on a daily basis, with daily maximums, minimums, means, and standard deviations. All but one of these reports are intersite comparisons for all sites where the parameters are monitored. The reports available are:

1. Site report with all parameters monitored at that site;
2. Intersite comparison of rainfall;
3. Intersite comparison of air temperature at 48 in.;
4. Intersite comparison of freezing temperatures;
5. Intersite comparison of air temperature at 15 cm;
6. Intersite comparison of relative humidity.

Each report covers a period of 28 days, except at year end. A sample of each type of report for the same period of 1–28 January 1993 is included in this report (Figs. 56–61).

In 1995, completely new sensor arrays were purchased along with data loggers that can handle many more inputs than the ones currently in use. The number of weather stations will be expanded to 11, with some stations being moved to revised core sites. Soil moisture and temperature will be recorded at all sites. In addition, all sites will record all of the other parameters currently being recorded only at selected sites. A solar panel will provide power to keep the 12v internal battery in the logger box charged. It is expected that the reliability and accuracy of data collection will be considerably enhanced, although the exact nature and extent of available report formats have yet to be determined.

DATE	TOTAL SOLAR RADIA-TION kWh/m^2	MAX 1 HOUR SOLAR RADIA-TION kWh/m^2	MEAN SOIL TEMP @ 10cm deg C	STD DEV SOIL TEMP @ 10cm deg C	MAX 1 HOUR SOIL TEMP @ 10cm deg C	MIN 1 HOUR SOIL TEMP @ 10cm deg C	MEAN WIND SPEED mph	STD DEV WIND SPEED	WIND MOVE-MENT miles	MAX 1 HOUR WIND SPEED mph	WIND DIRECTION 1 hr avg @ 4:XX pm degrees	MEAN AIR TEMP @ 48" deg C	STD DEV AIR TEMP @ 48" deg C	MAX 1 HOUR AIR TEMP @ 48" deg C	MIN 1 HOUR AIR TEMP @ 48" deg C	HOURS TEMP BELOW FREEZING #	MEAN RH @ 48" %	STD DEV RH @ 48" %	MAX 1 HOUR RH @ 48" %	MIN 1 HOUR RH @ 48" %	PRECIP mm	MAX 2 HOUR PRECIP mm	MEAN AIR TEMP @ 15cm deg C	STD DEV 2 HOUR AIR TEMP @ 15cm deg C	MAX 2 HOUR AIR TEMP @ 15cm deg C	MIN 2 HOUR AIR TEMP @ 15cm deg C	DATE
01-Jan-93	19.3	3.5	11.3	2.19	15.0	8.5	0.7	1.10	17.6	3.3	208	11.6	4.18	18.5	6.5	0	79.5	13.29	92.0	57.0	0	0	11.5	4.86	19.5	5.0	01-Jan-93
02-Jan-93	10.5	2.2	10.9	1.33	13.0	9.0	1.3	1.43	30.8	4.5	191	12.1	3.02	17.5	6.5	0	73.1	14.31	90.0	45.0	0	0	11.7	3.62	17.0	6.0	02-Jan-93
03-Jan-93	18.6	3.6	11.1	1.59	14.0	8.0	1.6	1.64	37.8	5.5	253	8.5	3.00	12.0	1.5	0	65.5	22.68	91.0	34.0	4	3	8.9	3.62	13.5	1.0	03-Jan-93
04-Jan-93	16.9	3.2	8.1	2.30	11.5	5.0	1.3	1.01	31.6	3.0	281	7.7	4.00	14.0	1.0	0	51.4	13.34	86.0	35.0	0	0	7.8	4.58	15.0	1.5	04-Jan-93
05-Jan-93	12.2	2.4	9.7	1.67	12.0	7.5	0.7	0.78	16.6	2.8	118	10.1	3.02	15.0	5.0	0	71.3	12.99	90.0	52.0	0	0	10.1	3.32	15.0	5.5	05-Jan-93
06-Jan-93	3.5	1.0	11.6	1.02	13.0	10.5	2.0	1.20	47.2	4.2	112	13.1	1.44	15.0	10.5	0	88.9	1.61	92.0	83.0	19	7	13.0	1.41	15.0	11.0	06-Jan-93
07-Jan-93	2.6	0.7	13.0	0.44	13.5	12.5	2.9	1.52	70.4	6.3	118	14.8	0.47	15.5	14.0	0	88.8	0.41	89.0	88.0	4	2	14.8	0.48	15.5	14.0	07-Jan-93
08-Jan-93	17.6	3.2	13.7	1.14	16.0	12.0	3.6	2.71	86.0	7.9	236	13.6	3.14	17.0	8.0	0	77.4	16.13	91.0	43.0	9	6	14.0	3.18	17.5	8.0	08-Jan-93
09-Jan-93	17.8	3.3	12.2	1.58	15.0	10.0	0.7	1.02	17.0	3.8	140	11.8	2.95	16.5	7.0	0	77.0	14.33	92.0	50.0	0	0	11.9	3.37	17.0	7.0	09-Jan-93
10-Jan-93	1.8	0.6	11.7	0.54	12.5	11.0	4.1	2.28	97.3	9.4	135	11.9	1.47	14.0	9.5	0	89.2	3.14	92.0	82.0	17	6	12.0	1.33	13.5	10.0	10-Jan-93
11-Jan-93	17.5	3.5	13.1	1.40	16.0	11.5	1.0	0.84	24.1	2.8	196	13.0	2.52	17.5	8.5	0	80.9	10.99	91.0	56.0	0	0	13.4	2.62	18.0	8.5	11-Jan-93
12-Jan-93	15.7	3.3	11.7	1.80	14.5	9.0	0.4	0.60	10.7	2.4	101	11.8	2.58	16.5	8.0	0	77.7	11.52	91.0	56.0	0	0	12.0	3.04	16.5	8.0	12-Jan-93
13-Jan-93	8.6	1.8	13.0	1.04	15.0	12.0	0.6	0.71	14.4	2.5	140	13.7	1.88	18.0	11.5	0	88.0	5.18	97.0	78.0	16	9	13.3	1.80	17.0	11.0	13-Jan-93
14-Jan-93	13.4	2.4	12.9	1.34	15.5	11.0	0.5	0.52	12.2	1.5	123	13.6	2.09	17.5	10.5	0	82.5	6.54	90.0	68.0	0	0	13.5	2.30	17.5	10.5	14-Jan-93
Mean	12.6	2.5	11.7		14.0	9.8	1.5		36.7	4.3		12.0		16.0	7.7		77.9		91.0	59.1			12.0		16.3	7.6	Mean
Maximum	19.3	3.6	13.7		16.0		4.1		97.3	9.4		14.8		18.5			89.2		97.0		19	9	14.8		19.5		Maximum
Minimum			8.1			5.0	0.4		10.7			7.7			1.0		51.4			34.0			7.8			1.0	Minimum
Total									513.7							0					69						Total

DATE	TOTAL SOLAR RADIA-TION kWh/m^2	MAX 1 HOUR SOLAR RADIA-TION kWh/m^2	MEAN SOIL TEMP @ 10cm deg C	STD DEV SOIL TEMP @ 10cm deg C	MAX 1 HOUR SOIL TEMP @ 10cm deg C	MIN 1 HOUR SOIL TEMP @ 10cm deg C	MEAN WIND SPEED mph	STD DEV WIND SPEED	WIND MOVE-MENT miles	MAX 1 HOUR WIND SPEED mph	WIND DIRECTION 1 hr avg @ 4:XX pm degrees	MEAN AIR TEMP @ 48" deg C	STD DEV AIR TEMP @ 48" deg C	MAX 1 HOUR AIR TEMP @ 48" deg C	MIN 1 HOUR AIR TEMP @ 48" deg C	HOURS TEMP BELOW FREEZING #	MEAN RH @ 48" %	STD DEV RH @ 48" %	MAX 1 HOUR RH @ 48" %	MIN 1 HOUR RH @ 48" %	PRECIP mm	MAX 2 HOUR PRECIP mm	MEAN AIR TEMP @ 15cm deg C	STD DEV 2 HOUR AIR TEMP @ 15cm deg C	MAX 2 HOUR AIR TEMP @ 15cm deg C	MIN 2 HOUR AIR TEMP @ 15cm deg C	DATE
15-Jan-93	9.6	2.1	12.9	1.27	15.0	11.5	0.4	0.44	8.8	1.5	151	13.9	1.95	18.0	11.5	0	82.3	5.62	89.0	70.0	0	0	13.8	2.27	18.0	11.0	15-Jan-93
16-Jan-93	17.4	3.5	14.3	1.69	17.0	12.0	1.3	0.91	30.2	2.9	140	15.6	2.55	20.0	11.5	0	79.3	9.53	90.0	63.0	1	1	15.7	2.91	20.5	11.5	16-Jan-93
17-Jan-93	5.9	1.3	14.4	0.46	15.5	14.0	2.4	1.44	57.1	5.2	151	15.5	0.92	17.5	14.5	0	86.2	1.72	88.0	82.0	0	0	15.5	0.89	17.0	14.5	17-Jan-93
18-Jan-93	14.3	3.6	14.0	0.93	16.0	12.5	2.6	2.90	63.0	9.3	185	13.3	2.30	17.5	9.5	0	85.3	6.05	90.0	67.0	5	3	13.8	2.19	18.0	10.0	18-Jan-93
19-Jan-93	21.8	3.8	13.0	2.03	16.5	10.5	0.6	0.69	13.2	2.9	208	11.7	3.07	16.5	7.0	0	78.1	12.49	91.0	56.0	0	0	12.0	3.50	17.5	8.0	19-Jan-93
20-Jan-93	21.9	3.6	12.3	2.23	16.0	9.5	0.9	0.75	21.1	3.0	264	12.0	3.71	18.0	7.0	0	71.9	14.31	91.0	47.0	0	0	12.3	4.00	19.0	7.5	20-Jan-93
21-Jan-93	22.8	3.8	12.2	2.42	16.0	9.0	1.3	1.33	31.3	4.6	292	12.3	4.79	19.0	4.5	0	66.8	17.80	92.0	40.0	0	0	12.3	5.43	20.0	4.5	21-Jan-93
22-Jan-93	22.6	3.5	12.5	2.48	16.5	9.5	1.1	1.20	27.1	4.2	230	13.8	5.10	23.5	6.5	0	70.0	18.37	91.0	35.0	0	0	13.7	5.76	23.0	6.0	22-Jan-93
23-Jan-93	23.9	3.9	12.9	2.24	17.0	10.0	2.1	1.44	51.1	4.8	286	13.6	3.25	19.5	9.5	0	57.0	19.08	87.0	32.0	0	0	13.7	3.94	20.5	9.0	23-Jan-93
24-Jan-93	23.6	3.8	12.2	2.58	16.5	8.5	1.3	1.07	31.2	3.7	303	12.5	5.60	20.5	2.5	0	45.8	20.30	89.0	27.0	0	0	12.4	6.33	22.0	2.0	24-Jan-93
25-Jan-93	23.0	3.9	12.9	2.42	17.0	10.0	2.5	1.50	61.0	4.5	348	14.8	4.47	21.5	6.0	0	25.3	16.03	67.0	10.0	0	0	15.0	4.78	22.5	5.5	25-Jan-93
26-Jan-93	15.4	2.5	11.9	1.78	15.0	9.0	0.5	0.76	11.4	2.9	230	12.4	4.84	20.0	3.5	0	49.5	18.64	81.0	26.0	0	0	11.8	5.43	20.5	2.5	26-Jan-93
27-Jan-93	13.5	3.8	13.0	2.09	16.0	10.5	0.8	1.10	18.4	4.0	185	14.1	4.52	22.5	8.0	0	58.8	19.44	84.0	33.0	0	0	13.9	5.02	23.0	7.5	27-Jan-93
28-Jan-93	24.0	3.9	14.5	2.32	18.5	11.5	0.7	0.98	16.7	2.8	180	13.5	4.76	20.5	7.0	0	71.3	19.10	92.0	43.0	0	0	13.9	5.31	22.0	7.5	28-Jan-93
Mean	18.6	3.4	13.1		16.3	10.6	1.3		31.5	4.0		13.5		19.6	7.8		66.3		87.3	45.1			13.6		20.3	7.6	Mean
Maximum	24.0	3.9	14.5		18.5		2.6		63.0	9.3		15.6		23.5			86.2		92.0		5	3	15.7		23.0		Maximum
Minimum			11.9			8.5	0.4		8.8			11.7			2.5		25.3			10.0			11.8			2.0	Minimum
Total									441.6							0					6						Total

Data File SB_93_01

Figure 56. Sample automated weather station report for the Senita Basin site, Organ Pipe Cactus National Monument, Arizona, 1–28 January 1993.

RAINFALL SITE COMPARISON: REPORTING PERIODS 1 & 2, 1993

	Armenta East PRECIP mm	Armenta East MAX 2 HOUR PRECIP mm	Aguajita Wash PRECIP mm	Aguajita Wash MAX 2 HOUR PRECIP mm	Bull Pasture PRECIP mm	Bull Pasture MAX 2 HOUR PRECIP mm	Bates Well PRECIP mm	Bates Well MAX 2 HOUR PRECIP mm	Gachado Well PRECIP mm	Gachado Well MAX 2 HOUR PRECIP mm	Headquarters PRECIP mm	Headquarters MAX 2 HOUR PRECIP mm	Neolloydia PRECIP mm	Neolloydia MAX 2 HOUR PRECIP mm	Senita Basin PRECIP mm	Senita Basin MAX 2 HOUR PRECIP mm	Salsola PRECIP mm	Salsola MAX 2 HOUR PRECIP mm	
01/01/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/01/93
01/02/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/02/93
01/03/93	4	3	2	2	5	4	3	2	4	3	5	4	2	2	4	3	5	3	01/03/93
01/04/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/04/93
01/05/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/05/93
01/06/93	13	6	16	7	35	13	12	7	10	5	20	9	17	9	19	7	12	8	01/06/93
01/07/93	20	8	3	2	22	7	14	8	3	2	5	2	7	3	4	2	7	3	01/07/93
01/08/93	5	5	8	5	33	30	8	7	6	3	15	14	13	9	9	6	8	4	01/08/93
01/09/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/09/93
01/10/93	21	8	9	3	60	11	18	4	13	3	28	8	27	8	17	6	13	3	01/10/93
01/11/93	3	1	3	1	3	2	0	0	8	6	4	4	8	5	0	0	1	1	01/11/93
01/12/93	1	1	0	0	2	1	1	1	0	0	0	0	1	1	0	0	0	0	01/12/93
01/13/93	4	2	6	3	22	10	6	3	21	7	18	10	5	3	16	9	17	5	01/13/93
01/14/93	0	0	3	3	0	0	0	0	0	0	1	1	0	0	0	0	1	1	01/14/93
Maximum	21	8	16	7	60	30	18	8	21	7	28	14	27	9	19	9	17	8	Maximum
Total	71		50		182		62		65		96		80		69		64		Total

	Armenta East PRECIP mm	Armenta East MAX 2 HOUR PRECIP mm	Aguajita Wash PRECIP mm	Aguajita Wash MAX 2 HOUR PRECIP mm	Bull Pasture PRECIP mm	Bull Pasture MAX 2 HOUR PRECIP mm	Bates Well PRECIP mm	Bates Well MAX 2 HOUR PRECIP mm	Gachado Well PRECIP mm	Gachado Well MAX 2 HOUR PRECIP mm	Headquarters PRECIP mm	Headquarters MAX 2 HOUR PRECIP mm	Neolloydia PRECIP mm	Neolloydia MAX 2 HOUR PRECIP mm	Senita Basin PRECIP mm	Senita Basin MAX 2 HOUR PRECIP mm	Salsola PRECIP mm	Salsola MAX 2 HOUR PRECIP mm	
01/15/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/15/93
01/16/93	0	0	1	1	2	1	0	0	5	3	1	1	1	1	1	1	8	7	01/16/93
01/17/93	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	01/17/93
01/18/93	3	2	2	1	17	7	0	0	9	4	13	3	2	1	5	3	4	2	01/18/93
01/19/93	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	01/19/93
01/20/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/20/93
01/21/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/21/93
01/22/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/22/93
01/23/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/23/93
01/24/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/24/93
01/25/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/25/93
01/26/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/26/93
01/27/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/27/93
01/28/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/28/93
Maximum	3	2	2	1	17	7	0	0	9	4	13	3	2	1	5	3	8	7	Maximum
Total	3		3		21		0		14		15		3		6		12		Total

Figure 57. Sample intersite rainfall comparison report for weather-monitored sites, Organ Pipe Cactus National Monument, Arizona, 1–28 January 1993.

AIR TEMPERATURE AT 48 INCHES, SITE COMPARISON: REPORTING PERIODS 1 & 2, 1993

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Senita Basin			Salsola			
	Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/01/93	10	19	3	13	24	4	16	20	15	11	18	6	10	21	3	11	20	3	12	19	7	10	21	4	01/01/93
01/02/93	11	16	4	13	23	5	16	17	15	11	17	7	11	20	3	11	18	5	12	18	7	11	19	3	01/02/93
01/03/93	7	12	-2	11	19	2	13	16	11	7	12	-1	9	14	0	9	12	4	8	12	2	8	14	-2	01/03/93
01/04/93	6	14	-3	8	17	-2	14	17	12	5	12	-2	6	15	-3	7	15	-3	8	14	1	5	14	-4	01/04/93
01/05/93	10	15	4	14	21	7	14	16	13	10	16	5	10	17	5	10	16	5	10	15	5	10	16	4	01/05/93
01/06/93	13	16	10	17	20	15	16	19	14	14	16	11	13	17	11	13	15	10	13	15	11	13	16	10	01/06/93
01/07/93	15	16	14	20	24	18	20	21	19	16	17	15	16	18	14	15	16	14	15	16	14	15	17	14	01/07/93
01/08/93	13	16	7	19	25	10	20	22	16	14	18	7	15	19	9	15	18	10	14	17	8	14	18	9	01/08/93
01/09/93	11	16	6	15	22	8	16	18	15	12	18	6	12	18	7	12	17	6	12	17	7	12	18	7	01/09/93
01/10/93	12	14	10	16	19	14	17	20	15	13	15	11	12	16	10	12	15	10	12	14	10	12	15	10	01/10/93
01/11/93	12	16	6	17	21	10	19	21	16	12	17	7	13	18	7	14	18	8	13	18	9	13	18	7	01/11/93
01/12/93	10	17	3	15	22	7	16	19	15	12	18	6	11	18	6	11	17	5	12	17	8	11	17	5	01/12/93
01/13/93	13	17	10	18	25	12	18	19	16	14	19	12	13	18	9	13	18	10	14	18	12	13	19	10	01/13/93
01/14/93	12	16	9	17	23	12	19	20	17	14	18	11	13	19	9	14	19	10	14	18	11	13	18	10	01/14/93
Mean	11	16	6	15	22	8	17	19	15	12	16	7	12	17	6	12	16	7	12	16	8	11	17	6	Mean
Maximum	15	19		20	25		20	22		16	19		16	21		15	20		15	19		15	21		Maximum
Minimum	6		-3	8		-2	13		11	5		-2	6		-3	7		-3	8		1	5		-4	Minimum

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Senita Basin			Salsola			
	Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			Air Temperature at 48 inches degrees C			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/15/93	13	19	9	19	37	13	18	19	17	14	20	11	13	20	9	14	19	10	14	18	12	13	19	8	01/15/93
01/16/93	15	20	11	19	25	15	18	20	16	16	21	12	16	22	11	16	21	11	16	20	12	15	20	11	01/16/93
01/17/93	15	18	15	20	22	18	19	20	18	17	19	16	16	19	15	16	18	15	15	18	15	16	18	15	01/17/93
01/18/93	13	17	9	17	22	14	19	21	18	14	19	8	14	18	10	14	18	9	13	18	10	14	18	10	01/18/93
01/19/93	11	16	7	14	20	9	19	22	18	12	17	7	11	18	6	12	18	8	12	17	7	11	17	5	01/19/93
01/20/93	10	19	4	13	21	5	19	22	18	11	18	6	11	21	3	11	19	4	12	18	7	10	19	3	01/20/93
01/21/93	11	19	5	15	22	7	19	22	18	12	21	7	12	21	3	13	20	7	12	19	5	11	22	2	01/21/93
01/22/93	12	23	6	15	25	6	20	24	18	13	23	7	13	25	6	14	23	4	14	24	7	12	24	4	01/22/93
01/23/93	11	18	6	15	23	7	19	22	17	12	20	6	12	21	6	13	19	10	14	20	10	11	22	3	01/23/93
01/24/93	11	19	5	14	23	6	16	20	13	9	20	-1	12	23	-1	13	20	8	13	21	3	10	23	-1	01/24/93
01/25/93	12	21	5	17	25	10	14	17	10	13	22	2	15	24	6	15	23	9	15	22	6	16	21	9	01/25/93
01/26/93	13	21	5	14	22	7	16	19	14	11	21	4	10	20	4	11	20	3	12	20	4	10	19	5	01/26/93
01/27/93	13	22	7	16	25	8	14	18	13	14	24	10	13	23	7	13	22	7	14	23	8	13	22	7	01/27/93
01/28/93	14	22	8	16	24	9	13	19	10	14	22	9	14	23	7	14	22	8	13	21	7	14	22	7	01/28/93
Mean	13	19	7	16	24	9	17	20	15	13	20	7	13	21	6	13	20	8	14	20	8	13	20	6	Mean
Maximum	15	23		20	37		20	24		17	24		16	25		16	23		16	24		16	24		Maximum
Minimum	10		4	13		5	13		10	9		-1	10		-1	11		3	12		3	10		-1	Minimum

Figure 58. Sample intersite air temperature at 48 in. comparison report for weather-monitored sites, Organ Pipe Cactus National Monument, Arizona, 1–28 January 1993.

ORGAN PIPE CACTUS NATIONAL MONUMENT 1993 FREEZING TEMPERATURES BY SITE	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Senita Basin			Salsola			
	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	
12/31 noon to 01/01 noon	0	3	0	0	4	0	0	10	0	0	5.5	0	0	3	0	0	3	0	0	6.5	0	0	3	0	
01/01 noon to 01/02 noon	0	4	0	0	4.5	0	0	14	0	0	6.5	0	0	3	0	0	5	0	0	6.5	0	0	3	0	
01/02 noon to 01/03 noon	0	7	0	0	9.5	0	0	12	0	0	8	0	0	8.5	0	0	7.5	0	0	8	0	0	8.5	0	
01/03 noon to 01/04 noon	9	-3	17	5	-2	6	0	11	0	8	-1	4	7	-2	11	2	-2	3	0	1	0	11	-3	23	
01/04 noon to 01/05 noon	0	4	0	0	7	0	0	12	0	0	5	0	0	4.5	0	0	4.5	0	0	5	0	0	3.5	0	
01/05 noon to 01/06 noon	0	10	0	0	14	0	0	14	0	0	10	0	0	10	0	0	10	0	0	10	0	0	10	0	
01/06 noon to 01/07 noon	0	13	0	0	17	0	0	15	0	0	14	0	0	12	0	0	13	0	0	13	0	0	13	0	
01/07 noon to 01/08 noon	0	14	0	0	20	0	0	20	0	0	15	0	0	15	0	0	14	0	0	14	0	0	14	0	
01/08 noon to 01/09 noon	0	5.5	0	0	7.5	0	0	14	0	0	6	0	0	6.5	0	0	5.5	0	0	7	0	0	7	0	
01/09 noon to 01/10 noon	0	9.5	0	0	13	0	0	14	0	0	11	0	0	10	0	0	9.5	0	0	9.5	0	0	9.5	0	
01/10 noon to 01/11 noon	0	10	0	0	13	0	0	16	0	0	11	0	0	12	0	0	11	0	0	11	0	0	11	0	
01/11 noon to 01/12 noon	0	3	0	0	7	0	0	15	0	0	6	0	0	5.5	0	0	5	0	0	8	0	0	5	0	
01/12 noon to 01/13 noon	0	10	0	0	15	0	0	15	0	0	11	0	0	12	0	0	11	0	0	11	0	0	11	0	
01/13 noon to 01/14 noon	0	9	0	0	12	0	0	18	0	0	12	0	0	9	0	0	9.5	0	0	11	0	0	10	0	
MAX	9		17	5		6	0		0	8		4	7		11	2		3	0		0	11		23	MAX
MIN		-3			-2			10			-1			-2			-2			1			-3		MIN
TOTAL	9		17	5		6	0		0	8		4	7		11	2		3	0		0	11		23	TOTAL

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Senita Basin			Salsola			
	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	
01/14 noon to 01/15 noon	0	8.5	0	0	12	0	0	16	0	0	10	0	0	8.5	0	0	9.5	0	0	10	0	0	8	0	
01/15 noon to 01/16 noon	0	11	0	0	14	0	0	16	0	0	11	0	0	11	0	0	11	0	0	11	0	0	11	0	
01/16 noon to 01/17 noon	0	14	0	0	18	0	0	17	0	0	15	0	0	14	0	0	14	0	0	14	0	0	14	0	
01/17 noon to 01/18 noon	0	13	0	0	17	0	0	19	0	0	14	0	0	14	0	0	13	0	0	14	0	0	14	0	
01/18 noon to 01/19 noon	0	8	0	0	9	0	0	18	0	0	8	0	0	6.5	0	0	7.5	0	0	7	0	0	5.5	0	
01/19 noon to 01/20 noon	0	3.5	0	0	5	0	0	17	0	0	6	0	0	2.5	0	0	4	0	0	7.5	0	0	3	0	
01/20 noon to 01/21 noon	0	4.5	0	0	7	0	0	18	0	0	0	0	0	3	0	0	6.5	0	0	4.5	0	0	2	0	
01/21 noon to 01/22 noon	0	5.5	0	0	5.5	0	0	17	0	0	7	0	0	5.5	0	0	4	0	0	6.5	0	0	3.5	0	
01/22 noon to 01/23 noon	0	5.5	0	0	7	0	0	18	0	0	6.5	0	0	5.5	0	0	9.5	0	0	9.5	0	0	3	0	
01/23 noon to 01/24 noon	0	4.5	0	0	6	0	0	15	0	1	0	0	1	-1	1	0	7.5	0	0	2.5	0	2	0	0	
01/24 noon to 01/25 noon	0	5	0	0	9.5	0	0	10	0	0	2	0	0	9	0	0	9.5	0	0	11	0	0	5.5	0	
01/25 noon to 01/26 noon	0	5	0	0	7	0	0	14	0	0	3.5	0	0	3.5	0	0	3	0	0	3.5	0	0	4.5	0	
01/26 noon to 01/27 noon	0	6.5	0	0	8	0	0	12	0	0	9.5	0	0	7	0	0	7	0	0	8	0	0	7	0	
01/27 noon to 01/28 noon	0	8	0	0	9	0	0	10	0	0	8.5	0	0	8	0	0	8	0	0	9	0	0	8	0	
MAX	0		0	0		0	0		0	1		0	1		1	0		0	0		0	2		0	MAX
MIN		3.5			5			10			0			-1			3			2.5			0		MIN
TOTAL	0		0	0		0	0		0	1		0	1		1	0		0	0		0	2		0	TOTAL

Figure 59. Sample intersite freezing temperatures comparison report, for weather-monitored sites, Organ Pipe Cactus National Monument, Arizona, 1-28 January 1993.

AIR TEMPERATURE AT 15 CENTIMETERS, SITE COMPARISON: REPORTING PERIODS 1 & 2, 1993

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Neolloydia			Senita Basin			Salsola			
	Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/01/93	10	19	2	10	19	3	12	18	8	11	19	4	10	20	3	11	19	4	11	19	6	12	20	5	10	20	3	01/01/93
01/02/93	10	16	3	10	17	3	11	14	8	11	17	6	10	18	2	11	17	5	12	16	6	12	17	6	11	18	4	01/02/93
01/03/93	6	12	-4	8	13	1	5	9	-1	7	13	-2	8	14	-2	9	12	4	8	14	2	9	14	1	8	13	-3	01/03/93
01/04/93	6	14	-5	5	13	-4	7	11	4	5	12	-3	5	15	-4	7	14	-2	7	13	2	8	15	2	5	14	-4	01/04/93
01/05/93	10	15	4	10	16	5	9	12	6	11	16	6	10	15	5	10	15	5	10	15	6	10	15	6	10	16	5	01/05/93
01/06/93	13	15	10	13	15	11	11	13	9	14	16	11	13	16	11	13	15	11	13	15	11	13	15	11	13	16	11	01/06/93
01/07/93	15	16	14	15	16	14	13	13	12	16	17	15	15	17	13	15	16	14	15	15	14	15	16	14	15	17	14	01/07/93
01/08/93	13	16	6	14	18	8	11	13	8	14	18	8	15	18	9	14	17	10	13	18	8	14	18	8	14	18	10	01/08/93
01/09/93	11	16	5	12	18	6	9	12	5	12	18	6	12	17	7	12	16	6	12	17	6	12	17	7	12	17	8	01/09/93
01/10/93	12	14	10	12	15	10	9	12	7	13	15	12	12	15	10	12	14	10	12	14	10	12	14	10	13	15	11	01/10/93
01/11/93	11	16	5	13	18	8	10	13	4	12	17	7	13	18	7	13	17	8	12	17	7	13	18	9	13	18	6	01/11/93
01/12/93	11	16	4	12	18	6	9	13	4	12	18	6	11	16	5	11	16	5	11	17	6	12	17	8	11	16	6	01/12/93
01/13/93	13	17	9	13	18	10	11	12	10	14	19	11	13	18	9	13	16	9	13	17	11	13	17	11	13	18	10	01/13/93
01/14/93	12	16	8	13	18	9	10	12	9	14	18	11	13	18	9	12	17	9	14	17	12	13	18	11	13	17	11	01/14/93
Mean	11	15	5	11	16	6	10	12	6	12	17	7	11	17	6	12	16	7	12	16	8	12	16	8	12	16	6	Mean
Maximum	15	19		15	19		13	18		16	19		15	20		15	19		15	19		15	20		15	20		Maximum
Minimum	6		-5	5		-4	5		-1	5		-3	5		-4	7		-2	7		2	8		1	5		-4	Minimum

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Neolloydia			Senita Basin			Salsola			
	Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/15/93	13	18	9	14	19	10	11	14	8	14	20	10	13	18	9	13	18	9	14	18	11	14	18	11	13	19	9	01/15/93
01/16/93	15	20	11	16	21	12	13	16	10	16	21	12	15	21	11	15	20	11	16	20	12	16	21	12	16	21	12	01/16/93
01/17/93	15	17	14	16	19	15	12	13	11	17	19	16	16	18	15	15	17	15	15	17	14	16	17	15	16	18	15	01/17/93
01/18/93	13	17	9	14	19	11	10	12	7	15	19	9	14	18	10	13	17	9	13	17	11	14	18	10	14	18	11	01/18/93
01/19/93	10	17	6	12	18	7	8	13	5	11	18	7	11	17	7	11	16	7	11	17	7	12	18	8	11	16	5	01/19/93
01/20/93	10	17	3	11	19	4	10	15	5	11	18	6	10	19	2	11	18	4	11	17	6	12	19	8	10	18	3	01/20/93
01/21/93	10	19	3	12	19	6	12	17	8	12	20	7	11	20	3	12	19	6	13	19	10	12	20	5	10	21	2	01/21/93
01/22/93	11	21	4	12	23	4	13	21	7	12	22	7	12	23	5	13	21	4	14	21	10	14	23	6	12	23	4	01/22/93
01/23/93	10	18	4	13	20	6	14	17	12	12	20	5	12	20	5	13	19	10	13	19	9	14	21	9	11	22	3	01/23/93
01/24/93	10	18	4	11	19	5	14	19	12	9	20	-1	11	21	-1	12	20	8	13	20	8	12	22	2	10	22	-1	01/24/93
01/25/93	12	21	4	15	22	9	14	17	10	13	22	3	14	22	5	14	22	9	15	21	12	15	23	6	15	22	7	01/25/93
01/26/93	13	21	5	11	19	6	15	19	13	11	19	6	10	19	3	11	18	3	14	20	11	12	21	3	10	19	5	01/26/93
01/27/93	13	22	6	13	22	7	14	18	11	14	23	9	13	22	8	13	21	7	14	22	9	14	23	8	14	22	8	01/27/93
01/28/93	13	21	7	13	22	8	13	19	9	13	23	8	14	22	7	14	21	8	14	22	9	14	22	8	14	22	7	01/28/93
Mean	12	19	6	13	20	8	12	16	9	13	20	7	12	20	6	13	19	8	14	19	10	14	20	8	12	20	6	Mean
Maximum	15	22		16	23		15	21		17	23		16	23		15	22		16	22		16	23		16	23		Maximum
Minimum	10		3	11		4	8		5	9		-1	10		-1	11		3	11		6	12		2	10		-1	Minimum

Figure 60. Sample intersite air temperature at 15 cm comparison report for weather-monitored sites, Organ Pipe Cactus National Monument, Arizona, 1–28 January 1993.

RELATIVE HUMIDITY SITE COMPARISON REPORTING PERIODS 1 & 2, 1993

	Armenta East % Relative Humidity			Aguajita Wash % Relative Humidity			Bull Pasture % Relative Humidity			Bates Well % Relative Humidity			Gachado Well % Relative Humidity			Headquarters % Relative Humidity			Senita Basin % Relative Humidity			Salsola % Relative Humidity			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/01/93	81	92	54	83	95	56	66	67	65	77	87	59	79	90	52	76	90	51	79	92	57	79	91	52	01/01/93
01/02/93	77	92	50	82	95	49	64	65	63	76	86	53	72	89	40	72	87	44	73	90	45	71	90	36	01/02/93
01/03/93	71	92	33	66	94	29	64	69	61	68	87	31	70	90	28	62	88	30	65	91	34	68	93	24	01/03/93
01/04/93	66	92	37	70	97	40	60	61	59	69	89	50	71	93	36	50	78	33	51	86	35	73	93	36	01/04/93
01/05/93	73	92	52	75	94	47	62	68	59	72	87	46	74	91	50	71	88	50	71	90	52	74	91	52	01/05/93
01/06/93	89	92	84	91	92	86	69	71	67	85	88	82	87	91	80	85	89	83	89	92	83	88	91	86	01/06/93
01/07/93	89	91	88	89	91	86	59	70	69	84	86	83	86	88	82	85	86	83	89	39	88	87	89	85	01/07/93
01/08/93	79	91	47	76	93	39	69	70	67	75	89	43	77	90	42	72	87	41	77	91	43	76	90	43	01/08/93
01/09/93	78	93	53	77	94	46	68	70	67	74	89	47	76	90	48	74	88	48	77	92	50	76	92	48	01/09/93
01/10/93	89	93	79	89	93	77	69	70	69	85	88	77	88	91	84	85	89	83	89	92	82	88	90	82	01/10/93
01/11/93	85	92	66	79	92	58	69	70	67	77	89	58	78	91	52	77	88	48	81	91	56	79	92	51	01/11/93
01/12/93	77	93	48	78	95	54	69	70	67	75	88	44	77	90	53	77	89	54	78	91	56	77	90	52	01/12/93
01/13/93	89	92	80	88	92	78	69	70	59	84	87	78	86	89	76	84	87	78	88	97	78	85	90	70	01/13/93
01/14/93	84	91	74	85	92	68	69	70	68	81	87	72	80	88	62	79	86	64	83	90	68	81	88	64	01/14/93
Mean	81	92	60	81	94	58	67	69	66	77	88	59	79	90	56	75	87	56	78	91	59	79	91	56	Mean
Maximum	89	93		91	97		69	71		85	89		88	93		85	90		89	97		88	93		Maximum
Minimum	66		33	66		29	60		59	68		31	70		28	50		30	51		34	68		24	Minimum

	Armenta East % Relative Humidity			Aguajita Wash % Relative Humidity			Bull Pasture % Relative Humidity			Bates Well % Relative Humidity			Gachado Well % Relative Humidity			Headquarters % Relative Humidity			Senita Basin % Relative Humidity			Salsola % Relative Humidity			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/15/93	84	91	65	83	92	65	69	69	68	80	87	65	82	88	64	80	86	66	82	89	70	82	91	65	01/15/93
01/16/93	80	91	61	80	92	58	68	69	67	77	87	60	77	88	56	77	87	59	79	90	63	79	90	60	01/16/93
01/17/93	86	91	78	87	91	82	69	69	68	83	86	76	83	87	74	83	86	79	86	88	82	85	89	75	01/17/93
01/18/93	85	92	65	84	91	59	69	70	68	80	89	62	83	90	70	83	89	66	85	90	67	85	91	69	01/18/93
01/19/93	81	92	58	78	93	50	68	69	66	76	88	51	78	90	54	76	87	53	78	91	56	79	92	52	01/19/93
01/20/93	77	93	50	74	94	44	67	69	65	73	88	46	73	90	39	71	90	45	72	91	47	75	91	43	01/20/93
01/21/93	74	93	47	72	94	45	64	65	63	70	89	39	69	91	41	68	88	44	67	92	40	71	91	35	01/21/93
01/22/93	74	93	36	73	95	38	61	63	60	74	88	43	73	90	36	69	91	38	70	91	35	73	91	36	01/22/93
01/23/93	69	92	37	59	93	30	55	59	47	60	88	28	61	89	32	60	85	34	57	87	32	64	91	18	01/23/93
01/24/93	51	79	30	45	71	27	32	46	22	56	90	24	51	92	25	41	52	31	46	89	27	61	92	24	01/24/93
01/25/93	35	64	10	26	45	8	20	26	14	35	87	10	27	75	7	23	43	5	25	67	10	16	40	9	01/25/93
01/26/93	34	61	15	58	90	34	11	25	6	57	84	30	63	85	30	56	86	29	50	81	26	59	86	29	01/26/93
01/27/93	57	76	34	68	93	34	38	58	10	55	83	27	67	86	35	64	86	33	59	84	33	67	88	33	01/27/93
01/28/93	68	91	36	74	93	38	58	65	46	69	87	35	69	90	33	66	90	37	71	92	43	69	91	31	01/28/93
Mean	68	86	44	69	88	44	53	59	48	67	87	43	68	88	43	66	82	44	66	87	45	69	87	41	Mean
Maximum	86	93		87	95		69	70		83	90		83	92		83	91		86	92		85	92		Maximum
Minimum	34		10	26		8	11		6	35		10	27		7	23		5	25		10	16		9	Minimum

Figure 61. Sample intersite relative humidity comparison report for weather-monitored sites Organ Pipe Cactus National Monument, Arizona, 1–28 January 1993.

Air Quality

Introduction

Federal land management areas are classified as Class I, II, or III areas to facilitate implementation of the Clean Air Act. Mandatory Class I areas, the most protected from increases in air pollution, were designated by Congress in 1977. The Class I areas consist primarily of national parks and national forest lands with designated wilderness. Since ORPI became a wilderness area in 1978, the monument falls under Class II status and is not afforded the same protection from air pollutants as Class I lands. However, ORPI contains outstanding scenic features and ecological resources that are vulnerable to the air environment.

Although a visibility-impairing copper smelter fifteen miles north of the monument was closed in 1985, new threats to air resources are increasing. Agricultural activities on the Mexican border affecting air quality include field burning, pesticide and herbicide use, and truck traffic on dirt roads. New industrial and urban development are planned in Sonoyta, Sonora, and increasing tourist and truck traffic through the monument have the potential to dramatically increase air pollutants. Organ Pipe Cactus is also affected by regional haze sources such as urban southern California, the industrialized Gulf coasts of Mexico and Texas, and the smelter regions of Arizona and New Mexico.

At present, ORPI cooperates with 3 different agencies to monitor aspects of air quality: the National Atmospheric Deposition Program (NADP), the Arizona Department of Environmental Quality (ADEQ), and the Arizona Radiation Regulatory Agency (ARRA). The air quality program will be expanded in the future to include visibility monitoring and ozone monitoring.

Project History

National Atmospheric Deposition Program

This program was initiated in 1978 to track geographical patterns and temporal trends in the chemical climate of North America. Rain samples are collected weekly at sites throughout the country, and chemistry measurements are performed both in the field and at the NPDP Central Analytical Laboratory. The program is administered by the National Atmospheric Deposition Program/National Trends Network (NTN) Coordination Office at Colorado State University. Various cooperating agencies across the country provide personnel and equipment for the program. Organ Pipe Cactus National Monument, 1 of 3 current NADP sites in Arizona, initiated sampling in 1980.

In 1993 and 1994, Organ Pipe Cactus participated in a special NADP study. The 1-week/2-week study was designed to compare the sample chemistry of 1-week samples with that of 2-week samples. Another Aerochem Metrics sampler was installed, but the collection bucket on the second sampler was changed every 2 weeks instead of every week. At the end of the study, NADP hopes to evaluate the stability of samples under field conditions and the viability of a 2-week sampling period at some or all of the NADP sites in order to reduce program costs.

Arizona Department of Environmental Quality

The Arizona Department of Environmental Quality (ADEQ) regulates air quality as mandated by the Federal Clean Air Act and Arizona State Statutes. Environmental Protection Agency plans for air quality standards are followed by the department. Among ADEQ projects is ambient monitoring of airborne particulates with a dichotomous (dichot) sampler. Sites monitored by ADEQ include areas with urban-related pollution, emissions from industrial facilities, and dust from agricultural operations. National Park Service sites in the program have the unique objective of monitoring visibility in pristine areas in accordance with federal regulations for visibility protection. A dichot sampler, measuring coarse and fine particulates less than 10 microns in diameter (PM_{10}), has been in place since 1991. Before that, a high-volume air sampler measured particulates with less resolution than the dichot method.

Arizona Radiation Regulatory Agency

Organ Pipe Cactus National Monument has 1 of 10 statewide continuous air sampling stations monitored by the Environmental Surveillance Program of the ARRA. The Statewide Environmental Sampling Program was initiated with the purpose of supplementing baseline data on radiation levels in the environs of the Palo Verde Nuclear Generating Station.

1994 Monitoring Activities

Buckets for the NADP study were collected weekly. Conductivity and pH measurements were made with samples with sufficient precipitation. The rest of the sample and other field data were sent to the NAPD/NTN Coordination Office.

Filters for ambient particulate (PM_{10}) and radiation monitoring were changed and sent to ADEQ and ARRA, respectively.

Methods

National Atmospheric Deposition Program

The ORPI NADP site equipment consists of an Aerochem Metrics wet/dry precipitation collector and a Belfort Universal rain gauge with event pen. These are located near the headquarters area. During precipitation events, the wet-side collection bucket is automatically uncovered, then covered when the event has ended. A cumulative weekly sample is collected. The Belfort Universal rain gauge records precipitation event times and precipitation weight on chart paper. In the ORPI lab, the bucket is weighed to determine precipitation amount. If rainfall is of sufficient volume, measurements of pH and specific conductance are then made. The sample is sent to the NADP Central Analytical Lab in Champaign, Illinois, where more extensive chemistry measurements are performed.

At the Central Analytical Lab, specific conductance is measured, as well as concentrations of hydrogen, ammonium, calcium, magnesium, sodium, potassium, sulfate, nitrate, and chloride. The monument receives monthly, seasonal, and annual data summaries as well as a yearly summary report for all U.S. NADP sites. Additionally, weekly records are kept and include copies of the Belfort rain gauge chart paper, a unique source of precipitation event data. These charts illustrate the time, duration, and rainfall amount of each precipitation event.

An additional component of the NADP is the U.S. Geological Survey Intersite Comparison Program. Twice a year or more, each NADP site is sent an identical rain sample. The sites perform conductivity and pH measurements. Each site then receives a report on the most probable values for the sample and a determination of the achievement of NADP accuracy goals at the site.

Arizona Department of Environmental Quality

The dichotomous particulate (PM_{10}) sampler at Organ Pipe is located near the NADP sampling equipment. Two filters collect coarse and fine particulate samples for a 24-hour period every 6 days. The filters are sent to ADEQ for gravimetric and optical density analysis.

Arizona Radiation Regulatory Agency

Filters are changed weekly in the continuous air sampler and sent to ARRA for analysis.

Results

National Atmospheric Deposition Program

Organ Pipe Cactus was one of 162 NADP sites that met the "completeness criteria" for 1993. The data from these sites were included in national summary maps of weighted mean concentrations and deposition estimates for various ions. These national summary maps along with annual, seasonal and weekly data summaries for each site in the NADP network are included in the *NADP/NTN Annual Data Summary, Precipitation Chemistry in the United States, 1993.* The annual report for 1994 is not yet completed. Since 1991, precipitation chemistry results for ORPI have not changed significantly. Weighted mean concentrations of sulfates (SO_4) and nitrates (NO_3), important components of acid deposition, have decreased a small amount. The 1994 summary from the annual report is presented in Figure 62, and Table 13 presents pH and weighted mean concentrations of SO_4 and NO_3 from 1990 to 1993.

Arizona Department of Environmental Quality

Results of PM_{10} monitoring are summarized in annual Air Quality Data for Arizona reports. Table 14 presents PM_{10} data from 1987–1992 for both Organ Pipe and Ajo sites. The sudden decrease in numbers in 1991 reflects an equipment switch from Sierra Anderson high volume samplers to dichotomous samplers that measure lower PM_{10} concentrations. The new equipment was chosen to determine particle size fractions and chemical components.

Arizona Radiation Regulatory Agency

The reports for 1993 and 1994 background radiation levels have not yet been received. No increase in environmental background radiation levels was reported in previous reports.

National Atmospheric Deposition Program/National Trends Network

1993 ANNUAL & SEASONAL DATA SUMMARY
(Printed 06/07/94)

SITE IDENTIFICATION	
Site	Organ Pipe Cactus Nat'l Mon.
State	AZ
County	Pima
Operation	NPS
Funding	NPS
Site No.	030620
CAL Code	AZ06
Latitude	31:57:02
Longitude	112:48:00
Elevation	506 m

SAMPLE VALIDITY FOR ANNUAL PERIOD	
Sampling Intervals	53
Valid Samples	51
with precipitation	22
with full chemistry#	(19)
without chemistry	(3)
without precipitation	29
Invalid Samples	2
with precipitation	2
missing precipitation data	0

SUMMARY PERIOD INFORMATION	Annual	Winter	Spring	Summer	Fall
First summary day (yrmoda)	921229	921201	930302	930601	930831
Last summary day (yrmoda)	940104	930302	930601	930831	931130
Summary period (days)	371	91	91	91	91
Sampling intervals	53	13	13	13	13
Measured precipitation (cm)	30.3	21.9	1.2	9.8	5.1
Valid samples with full chemistry#	19	10	2	3	4
Valid samples with full chemistry & valid field pH	12	9	1	1	1

NADP/NTN COMPLETENESS CRITERIA	Annual	Winter	Spring	Summer	Fall
1. Summary period with valid samples (%)	98.1	100.0	92.3	92.3	100.0
2. Summary period with precipitation coverage (%)	100.0	100.0	100.0	100.0	100.0
3. Measured precipitation with valid samples (%)	99.6	100.0	93.9	99.5	100.0
4. Collector efficiency (%)	106.4	104.2	106.7	102.0	107.2
Measured precip. with full chem. & valid field pH (%)	96.9	75.3	91.9	96.0	92.0

STATISTICAL SUMMARY OF PRECIPITATION CHEMISTRY FOR VALID SAMPLES

PRECIPITATION-WEIGHTED MEAN CONCENTRATIONS	Ca	Mg	K	Na	NH4	NO3 (mg/L)	Cl	SO4	H(lab)	H(fld)	pH (lab)	pH (fld)
Annual	0.06	0.041	0.030	0.329	0.09	0.28	0.56	0.37	3.17e-3	5.37e-3	5.50	5.27
Winter	0.04	0.021	0.010	0.172	0.05	0.19	0.28	0.33	4.69e-3	7.24e-3	5.33	5.14
Spring	0.16	0.075	0.032	0.555	0.07	0.36	0.94	0.51	2.46e-3	5.37e-3	5.61	5.27
Summer	0.03	0.006	0.038	0.053	0.16	0.29	0.06	0.27	1.86e-3	4.07e-3	5.73	5.39
Fall	0.13	0.130	0.060	1.049	0.12	0.50	1.92	0.61	3.27e-3	5.01e-3	5.49	5.30
DEPOSITION						kg/ha						
Annual	0.18	0.124	0.091	0.997	0.28	0.84	1.71	1.11	9.60e-3	1.63e-2	--	--
Winter	0.08	0.046	0.022	0.377	0.11	0.43	0.61	0.71	1.03e-2	1.59e-2	--	--
Spring	0.02	0.009	0.004	0.069	0.01	0.04	0.12	0.06	3.06e-4	6.68e-4	--	--
Summer	0.03	0.006	0.037	0.052	0.16	0.28	0.06	0.26	1.82e-3	3.98e-3	--	--
Fall	0.06	0.066	0.031	0.536	0.06	0.25	0.98	0.31	1.67e-3	2.56e-3	--	--
WEEKLY SAMPLE CONCENTRATIONS						mg/L						
Minimum value	0.01	0.004	0.003	0.042	0.02	0.08	0.05	0.19	9.77e-5	3.89e-3	4.71	4.61
Percentile 10	0.02	0.007	0.003	0.042	0.02	0.08	0.07	0.22	1.86e-4	3.95e-3	4.82	4.68
Percentile 25	0.07	0.010	0.013	0.109	0.06	0.32	0.10	0.39	7.41e-4	5.10e-3	5.38	4.96
Percentile 50	0.13	0.039	0.036	0.302	0.10	0.62	0.42	0.71	2.29e-3	8.97e-3	5.64	5.05
Percentile 75	0.32	0.074	0.071	0.627	0.23	1.69	0.76	1.37	4.17e-3	1.09e-2	6.13	5.29
Percentile 90	0.74	0.185	0.145	1.090	1.06	3.56	2.04	2.76	1.51e-2	2.13e-2	6.73	5.40
Maximum value	1.57	0.186	0.151	1.660	1.29	3.63	2.80	3.03	1.95e-2	2.45e-2	7.01	5.41
Arithmetic mean	0.28	0.059	0.049	0.461	0.26	1.11	0.65	0.96	4.19e-3	9.35e-3	5.38	5.03
Arith. std. dev.	0.38	0.057	0.046	0.433	0.37	1.15	0.72	0.82	5.45e-3	5.76e-3	--	--
Below detection	0	0	2	0	2	0	0	0	0	0	0	0

OTHER PARAMETERS	Measured Precipitation** cm	Conductivity uS/cm	Equivalence Ratios SO4/NO3	Equivalence Ratios SO4+NO3/H(lab)	Equivalence Ratios Cation/Anion
Minimum value	0.03	3.1	0.56	1.41	0.62
Percentile 10	0.03	3.3	0.81	1.49	0.67
Percentile 25	0.13	4.8	0.98	4.37	0.93
Percentile 50	0.28	9.4	1.18	5.68	0.98
Percentile 75	1.19	15.7	2.11	78.08	1.19
Percentile 90	6.81	22.0	3.55	223.36	1.42
Maximum value	9.37	40.1	3.87	1233.45	1.56

OTHER ANNUAL & SEASONAL DEPOSITION VALUES	Total N from NO3 & NH4 (kg/ha)	Equivalence Ratios SO4/NO3	Equivalence Ratios SO4+NO3/H(lab)	Equivalence Ratios Cation/Anion
Annual	0.41	1.70	3.82	1.06
Winter	0.18	2.16	2.12	1.05
Spring	0.02	1.85	6.72	1.06
Summer	0.18	1.22	5.52	1.33
Fall	0.10	1.59	6.35	0.99

Valid samples for which all laboratory chemical measurements were made (the only samples described by the percentile distributions in the STATISTICAL SUMMARY OF PRECIPITATION CHEMISTRY FOR VALID SAMPLES).

** Measured precipitation for sample periods during which precipitation occurred and for which complete valid laboratory chemistry data are available.

Figure 62. National Atmospheric Deposition Program annual and seasonal data summary for Organ Pipe Cactus National Monument, Arizona, 1994.

Table 13. Weighted mean concentrations of NO_3, SO_4 and pH for National Atmospheric Deposition Program 1990–1994 rainfall samples at Organ Pipe Cactus National Monument, Arizona. NO_3 and SO_4 figures in mg/L. The spring 1990 sampling period did not meet the NADP sample validity criteria.

	Annual			Winter			Spring			Summer			Fall		
	NO_3	SO_4	pH	NO_3	SO_4	pH	NO_3	SO_4	pH	NO_3	SO_4	pH	NO_3	SO_4	pH
1990	0.98	0.81	5.34	0.24	0.78	5.76	0.97	20.36	7.71	1.29	0.85	5.32	0.76	0.89	5.24
1991	0.72	0.81	5.24	0.40	0.43	5.21	0.16	0.31	5.98	1.50	1.43	5.06	0.75	0.97	5.15
1992	0.58	0.52	5.27	0.23	0.35	5.45	0.21	0.27	5.45	1.34	0.91	5.11	0.87	0.95	5.15
1993	0.28	0.37	5.50	0.19	0.33	5.33	0.36	0.51	5.61	0.29	0.27	5.73	0.50	0.61	5.49
1994	0.51	0.57	5.30	0.17	0.22	5.32	0.34	0.43	5.45	0.92	0.97	5.95	0.79	0.90	5.00

Table 14. PM_{10} concentrations for Organ Pipe Cactus and Ajo Sampling Sites, Arizona. PM_{10} is measured in $\mu g/m^3$. State and Federal regulations set a standard of 150 $\mu g/m^3$, not to be exceeded more than once per year over a 3-year period.

	Organ Pipe Cactus N.M.			Ajo		
	Annual Arithmetic Mean	24-hour Average Max	24-hour Average 2nd Hi	Annual Arithmetic Mean	24-hour Average Max	24-hour Average 2nd Hi
1987	17	105	36	39[1]	253[2]	102
1988	16	53	46	42[1]	102	71
1989	19	65	50	41[1]	123	86
1990	23	108	108	44[1]	121	112
1991	11	36	26	31[1]	80	74
1992	11	30	24	23[1]	47	42
1993	10	23	19	23[1]	51	45
1994	9	22	17	19[1]	38	30

[1] Based on a limited number of samples. [2] Exceeded State and Federal standards.

Land Use Trends

Introduction

In the Land Use Trends Surrounding Organ Pipe Cactus National Monument project, conducted from 1987 to 1988, researchers examined agricultural development in the Sonoyta Valley adjacent to the monument in Sonora, Mexico. Agricultural (and urban) development in this area has the potential to negatively impact the natural resources of the monument through depletion of the aquifer that is shared by the monument and Mexico in the Rio Sonoyta watershed. In addition, other aspects of agricultural development are of concern. The aerial application of agricultural pesticides is a threat due to wind drift. Increased human habitation causes impact from pollution, habitat degradation, woodcutting, livestock trespass, and nonnative plants and animals.

The Mexican portion of the Sonoyta Valley is a prime site for agricultural development. In 1988, at the conclusion of the research phase of the project, more than 12,140 ha had been developed for irrigated agriculture. Total water withdrawal from the approximately 165 agricultural wells in 1987–1988 was estimated to be 83,152 acre-feet, more than 2.5 times the annual groundwater recharge rate of 28,135 acre-feet. Although moratoriums are currently in effect to (1) prohibit development of new wells for irrigation and (2) limit the land developed for irrigated agriculture to the present 12, 950 ha, this is of little reassurance when one realizes that the total current annual pumping capacity in the Sonoyta Valley is estimated to be 191,000 acre-feet, or more than 6 times the estimated annual groundwater recharge rate.

Four different methods were recommended in the monitoring protocol to track agricultural development in the Sonoyta Valley:

1. Bi-annual photo-point photography of the agricultural area to detect changes through time;
2. Periodic aerial photography of the same area;
3. Collection of data from Mexican agricultural officials on crops, acreage, and chemical use;
4. Computation based on well depths and electrical use of the amount of water being pumped for agriculture.

Program History

Monument resource management staff has conducted the agricultural photo-point monitoring protocol since 1988. These photo-points are located adjacent to the international border, both in Mexico and the United States, and offer long-term visual information on changes in land use.

As recommended in the Land Use Trends final report, a good working relationship has been maintained with Mexican agricultural officials from the Secretaria de Agricultura y Recursos Hidráulicos (SARH) located in Sonoyta, Sonora. Monument esource management staff has regularly provided depth-to-water data from monument wells and agricultural photo-point photos

to these officials. In return, the monument receives annual data on depth-to-water and electricity use at Mexican agricultural wells, and information on crops and pesticide use.

1994 Monitoring Activities

Photos were taken in April and November at 8 border photo-points. Information from SARH on well depths, electricity use, and crops has not yet been received as of summer 1995 due to delays inherent in the centralization of agricultural data in Caborca, Sonora, which is almost 160 km south of the monument. Upon receipt of the necessary figures from SARH and the Comision Federal de Electricidad (CFE), the Lotus spreadsheets will be completed. A summary of the well use for 1993 is provided here (Fig. 63) and a summary of crop acreage for the last 12 years (Fig. 64).

Methods

Agricultural Photo-points

Twice each year, in April and November, a sequence of photos is taken from each of the 8 established photo points along the border. Four points are on the Mexican side of the border, while 4 are on the U.S. side. Each photo-point consists of a tagged rebar and 3 painted spots indicating the placement of the tripod. The head of the tripod is leveled by shortening 2 of the legs, and thus the photos are taken from exactly repeatable locations. Each individual photo in each panoramic sequence is located by means of comparison to existing black-and-white photos that are contained in the monitoring field book. Each photo sequence is shot using both color slide and black-and-white print film. Once processed, the slides, prints, and negatives are labeled and archived. One duplicate set of black-and-white prints is provided to SARH.

Mexican Agricultural Data

Soon after the beginning of each year, electrical and well-depth data are retrieved from Mexican agriculture and utility officials. These data are entered into a complex Lotus 1-2-3 spreadsheet that calculates, using assumed pump efficiencies, the amount of water being drawn from each well. A copy of this spreadsheet, when completed, is provided to SARH.

Results

All 8 boundary photo points were visited and photos taken without incident in 1994. Slides and prints showing Mexican agricultural development on the monument boundary were processed and archived in the monument museum vault.

Well depth and electrical data from Mexico for 1992 and 1993 were not received until early 1994. These figures were processed and entered into the appropriate Lotus 1-2-3 spreadsheets. Information was also obtained on the general distribution of crop acreage and the use of pesticides, herbicide, and fertilizers in the Sonoyta Valley. A vexing problem is the incomplete nature of the well data due to difficulties encountered by Mexican officials in measuring wells. This is due to blockage of the access hole or excessive oil (from leaky electric pumps) in the well. In addition, the calculations involved in the spreadsheet are based on 2 different ways of considering well depths. One is to use the static level, meaning the water level when no water is being pumped. This figure is currently the only one available, and is obtained each year in

November when all wells in the district are shut down for a period of 3 days, after which the water levels are measured. The other measure is the dynamic level, which is taken while the pumps are active, and which provides a more realistic basis for calculations of water withdrawal based on energy usage. Unfortunately, these figures have not been available since the original work on this project was done. Thus, the dynamic water level figures given are either old numbers, estimates, or duplications of the static levels. All of these above-stated difficulties and omissions are a continuing problem with this protocol, although the final figures give a reasonable estimate of water withdrawal in the area. A table of comparisons of total energy usage, total water withdrawals, based on both sets of well depths, and total crop acreage is here provided.

One conclusion that is indicated in every category given in Table 15 is that agriculture has been going through a period of decline in the Sonoyta area in the last few years. From discussions with officials at SARH, it would appear that the reason is primarily the combination of low crop prices and the increased cost of production, such as fertilizers, other chemicals, and the energy to run the pumps at the wells. In reviewing the electricity meter books provided by the CFE, it is clear that an increasing number of wells have had the electricity turned off due to lack of payment. Recent discussions have indicated, however, that cotton prices have climbed due to crop failures elsewhere in the world, and that the Mexican government is providing greater assistance to agricultural development in the Sonoyta area. So, the future of agriculture in the area is uncertain, but probably improving relative to the last few years. An additional note needs to be made, and that is that this protocol does not include data for the wells (there are now 2) used for the municipal water supply (water used for drinking, washing, industrial use, etc.). Even though agricultural water use may fluctuate, the urban population is growing, along with small industry. This trend, which will likely be exacerbated by the North American Free Trade Agreement (NAFTA), will need to be addressed in future attempts to gauge water withdrawals in the Sonoyta area.

ASSUMED LEVEL OF PUMP EFFICIENCY = 45 %

WELL	EJIDO	VOLUME AT STATIC LEVEL (m3)	VOLUME AT DYNAMIC LEVEL (m3)	STATIC LEVEL (m)	DYNAMIC LEVEL (m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL ENERGY (kW)
						MONTHLY VOLUME (m3) EXTRACTED BASED ON DYNAMIC LEVEL												
4.11	Ejido Cerro Colorado	1,491,862	458,894	5.41	17.47	0	0	0	0	0	0	196,296	227,068	35,530	0	0	0	48,511
5.05	Figueroa Uribe Aurelio	152,094	69,335	11.26	24.70	0	0	0	0	0	0	29,987	22,079	8,290	4,951	4,026	0	10,363
5.08	Figueroa Uribe Aurelio	0	0	8.67	24.70	0	0	0	0	0	0	0	0	0	0	0	0	0
5.24	Jaime Sierra Loreto	412,359	150,373	15.30	39.34	0	6,431	13,808	38,101	17,866	36,664	26,654	16,757	2,336	920	935	0	19,177
5.29	Flores Altamirano Rafael	2,728,328	674,148	7.86	31.81	1,927	2,598	7,029	65,657	115,941	115,172	149,403	148,536	8,660	57,500	1,725	0	129,764
5.31	Ejido Morelia	0	0	15.32	40.00	0	0	0	0	0	0	0	0	0	0	0	0	0
5.01	Ejido Morelia	1,000,068	640,544	25.62	40.00	0	0	0	30,242	66,434	157,161	219,133	166,085	0	0	1,431	0	155,040
6.02	Ejido Papago	964,553	957,060	29.74	30.00	275	0	0	90,457	191,337	134,190	60,061	331,173	47,044	2,522	0	0	155,595
6.09	Ejido Morelia	1,170,397	791,656	16.91	25.00	0	3,173	77,738	120,573	96,776	138,024	188,792	164,994	1,586	0	0	0	119,760
6.20	Ejido Hombres Blancos, No 3																	51,826
6.35	Ejido Hombres Blancos, No 1																	205,344
6.35	Ejido Hombres Blancos, No 2	0	0	16.38	15.47	0	0	0	0	0	0	0	0	0	0		0	0
6.40	L. Internacional Pozo #2																	4,604
6.42	Ejido Sonoyta Papagos No.2																	129,143
6.43	Ejido Sonoyta Papagos No 3																	162,530
7.01	San Martin	1,069,030	775,203	22.32	30.78	0	10,137	146,247	143,896	72,874	156,336	134,135	92,224	19,001	177	177	0	144,384
7.05	SPR de R.I. San Pedro	1,264,554	737,230	21.32	36.57	352	99	41,633	114,574	39,035	124,669	93,699	99,042	54,124	91,256	73,745	0	163,141
7.09	SPR de R.I. Los Angeles	1,757,742	1,076,978	16.01	26.13	0	0	117,838	216,298	200,999	67,944	179,856	242,930	49,736	980	393	0	170,287
7.10	Col. Emiliano Zapata	27,405	17,831	19.52	30.00	0	0	1,383	6,572	5,107	1,829	1,432	925	231	226	[illegible]	0	3,237
7.12	Julio/Rafael Mun	1,459,249	697,353	19.88	41.60	12,450	112,928	135,310	135,504	62,357	79,694	78,724	78,724	671	938	[illegible]	0	175,542
7.15	Col. E. Obregonista	185,383	186,984	16.35	16.21	2,192	2,773	2,834	3,905	11,174	16,240	11,061	26,466	58,794	4,486	47,050	0	18,341
7.15	Const / Cap Molina	121,548	59,217	13.69	28.10	218	506	1,212	1,359	1,176	16,126	13,785	8,545	1,223	323	[illegible]	0	10,059
7.19	Lopez Mateos	419,411	309,871	20.00	27.07	0	0	0	11,477	19,688	36,080	66,085	113,654	48,137	14,745		0	50,758
7.21	Julio/Rafael Mun	932,155	561,759	25.51	42.33	0	25,712	260,206	246,733	29,109	0	0	0	0	0	0	0	143,891
7.23	Ejido Desierto de Sonora	362,031	334,563	34.88	37.75	8,182	4,365	9,088	38,865	33,463	56,494	75,424	67,347	16,119	14,165	11,049	0	76,424
7.24	B. de Las Americas	0	0	34.98	40.00	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	Ejido Desierto de Sonora	404,413	340,638	34.88	41.41	0	0	9,187	30,901	17,392	69,368	102,687	107,732	3,372	0	0	0	85,356
7.26	Ejido Desierto de Sonora	466,647	467,050	46.35	46.31	0	856	43,679	71,942	104,201	85,645	117,904	38,255	0	4,568	0	0	130,860
7.27	Lopez Mateos	819,204	655,130	16.85	21.07	0	52,064	128,301	125,046	67,939	71,437	80,253	85,249	44,840	0	0	0	83,527
7.28	SPR Guadalupe	0	0	33.19	39.93	0	0	0	0	0	0	0	0	0	0	0	0	0
7.31	SPR de R.I. Los Angeles	2,020,964	825,963	22.18	54.27	0	0	68,725	175,953	203,305	34,392	150,380	119,783	73,116	134	174	0	271,241
8.01	SPR Los Nanos	3,213,325	1,864,301	26.05	44.90	32,360	70,211	172,561	225,179	265,143	221,351	228,352	261,606	155,266	142,623	89,649	0	506,521
8.02	SPR Los Mesquites	1,039,582	1,046,935	41.29	41.00	0	148,007	273,524	294,564	187,911	0	41,355	52,238	24,668	24,668	0	0	259,740
8.03	SPR Los Mesquites	1,010,153	753,941	41.05	55.00	0	0	0	150,896	186,051	164,418	115,200	78,423	58,952	0	0	0	250,920
8.04	SPR Los Mesquites	862,454	465,323	34.46	63.87	1,449	3,933	28,151	38,501	27,944	1,035	42,020	37,880	45,953	31,463	206,954	0	179,840
8.09	SPR Los Nanos	44,790	34,739	31.00	39.97	0	0	0	0	0	0	0	0	0	0	34,739	0	8,402
8.23	Francisco I. Madero	118,512	86,431	30.12	41.30	0	0	3,201	26,890	37,133	15,686	3,521	0	0	0	0	0	21,600
8.24	Francisco I. Madero	2,344,952	1,740,182	30.27	40.79	20,743	44,729	154,279	209,703	233,040	254,107	213,269	207,110	161,086	220,723	21,392	0	429,520
8.29	Col. Sonoyta	909,041	519,836	42.54	74.39	0	16,884	88,150	113,209	118,540	45,852	38,210	40,165	42,475	16,350	0	0	234,000
8.30	Col. Sonoyta	1,314,160	918,945	49.76	103.65	0	17,793	145,600	147,131	115,370	35,013	12,054	16,071	180,039	154,401	35,477	0	576,360
8.32	Col. Sonoyta	1,744,623	916,273	40.33	76.79	0	0	154,434	179,054	118,107	74,204	52,855	28,408	175,094	109,943	24,276	0	425,760
8.37	Ejido Tetabiate No.2	52,018	62,343	40.29	40.03	0	0	0	0	40,078	21,771	495	0	0	0	0	0	15,120
8.38	Col. Francisco I. Madero	374,357	209,879	33.91	60.00	28,755	8,924	84,282	71,722	6,610	6,280	3,305	0	0	0	0	0	76,200
8.40	Capitan Molina No.8	3,795,534	2,225,490	42.68	72.79	18,163	181,628	234,845	234,845	272,987	215,956	220,678	534,532	115,879	195,977	0	0	980,240
9.04	Ejido Desierto de Sonora	208,356	178,893	65.94	76.80	0	0	0	0	50,496	36,994	35,879	55,523	0	0	0	0	83,136
10.02	S.P.R. Pericales de R.I.	254,782	237,797	70.00	75.00	0	0	0	881	27,323	62,578	30,320	45,479	61,873	9,343	0	0	107,920
10.03	S.P.R. de R.I. Pericales	699,753	653,103	70.00	75.00	0	0	0	0	58,700	186,148	65,310	153,096	137,231	52,619	0	0	296,400
11.09	S.P.R. El Cumplimiento																	15,680
11.10	Col. Cuauhtemoc	0	0	56.24	80.00	0	0	0	0	0	0	0	0	0	0	0	0	0
11.11	Col. Cuauhtemoc	155,925	129,565	57.05	73.06	0	0	0	0	1,267	47,592	30,582	18,458	16,829	14,658	[illegible]	0	57,280
12.02	Col. A. Obregon	249,681	205,431	94.94	115.39	0	0	229	10,885	36,893	40,788	68,630	38,841	8,249	687	229	0	143,440
20.05	Col. Sonoyta	0	0	41.52	60.00	0	0	0	0	0	0	0	0	0	0	0	0	0
21.01	S.P.R.I Reforma	1,036,975	984,734	55.23	58.16	0	0	0	36,598	186,399	133,207	152,757	170,714	100,019	205,039	0	0	346,560
21.03	Col. CNCI Fracso	1,398,704	1,078,968	75.00	96.53	0	1,917	55,606	169,282	193,661	136,138	149,560	106,829	124,633	88,476	52,865	0	630,240
21.06	Col. CNCI Fracso	317,499	215,442	57.63	84.93	0	0	0	0	130,604	64,913	19,925	0	0	0	0	0	110,720
21.07	S.P.R. Las Delicias	374,795	250,863	80.32	120.00	0	0	7,502	50,734	39,827	37,844	26,441	37,018	17,022	22,540	11,733	0	182,160
21.09	Col. America	789,464	597,695	101.45	134.00	0	0	5,314	43,609	120,762	102,609	122,144	51,896	42,622	48,147	59,592	0	484,640
21.10	Col. America	1,406,246	1,105,795	89.34	114.25	0	453	23,375	79,151	228,658	208,291	238,609	65,959	101,368	88,971	71,050	0	764,480
21.13	Col. CNCI Fracso	479,096	362,585	71.14	94.00	0	141	22,644	55,133	83,262	47,398	68,495	56,399	26,019	2,954	141	0	206,240
21.14	Col. CNCI Fracso	1,558,353	1,513,721	69.39	76.02	0	3,478	74,782	86,955	263,649	290,779	119,651	134,607	266,779	219,923	53,217	0	636,320
21.15	Col. CNCI Fracso	5,690	5,378	69.70	73.75	0	359	359	359	717	0	717	717	1,434	359	359	0	2,400
21.16	S.P.R. Las Delicias	1,359,918	1,199,055	82.44	93.50	26,300	58,822	88,798	121,319	173,071	164,587	184,666	104,352	117,643	108,311	51,166	0	678,400
21.18	Col. CNCI Fracso	1,508,392	1,115,383	72.03	97.41	0	0	121,641	158,668	122,023	138,564	133,474	93,139	154,596	155,232	38,045	0	657,450
21.19	Col. America	0	0	87.87	102.74	0	0	0	0	0	0	0	0	0	0	0	0	0
22.04	Col. Grupo Valdez	722,706	587,881	73.21	90.00	0	0	0	1,469	170,107	0	130,444	160,705	117,517	7,639	0	0	320,160
22.07	S.P.R. Jose L. Portillo	1,077,612	647,815	57.11	95.00	0	0	417	70,418	85,448	9,185	169,921	175,905	121,631	14,891	0	0	372,400
22.09	S.P.R. Cuatro Cerros	0	0	90.00	90.00	0	0	0	0	0	0	0	0	0	0	0	0	0
22.10	Col. 21 de Marzo II Frac	737,102	670,479	99.33	109.20	908	86,443	129,493	189,231	90,802	51,575	66,648	54,844	545	0	0	0	443,040
22.11	Col. 21 de Marzo II Frac	368,178	343,002	94.96	101.93	195	23,930	56,032	86,383	47,861	37,938	58,561	17,510	14,592	0	0	0	211,560
22.12	Col. 21 de Marzo I Frac	410,591	402,053	97.95	100.03	0	0	0	397	64,498	60,929	118,554	58,815	91,724	7,137	0	0	243,360

Figure 63. Water usage for the Sonoyta Agricultural District, Sonora, Mexico, 1993.

22.13	S.P.R. Jose L. Portillo	351,789	216,159	67.59	110.00	3,065	0	49,037	56,969	65,983	0	15,865	14,423	10,637	180	0	0	143,880
22.14	Ejido La Nariz	786,263	711,431	75.01	82.90	1,914	5,622	80,377	119,728	105,973	120,804	127,024	36,514	65,545	40,667	5,263	0	356,880
23.08	S.P.R. El Cumplimiento	6,796	5,267	72.95	94.13	0	0	211	421	421	632	632	421	211	2,317	0	0	3,000
23.09	SPR Tomas Urbina	1,406	1,328	84.61	89.57	0	0	0	0	0	0	0	886	443	0	0	0	720
23.10	SPR Tomas Urbina	2,545	1,784	88.32	126.00	0	0	0	0	0	0	0	0	0	0	1,784	0	1,360
23.11	Col. Direccion del Norte	37,047	29,294	92.07	116.44	0	0	0	0	0	2,044	0	0	0	20,948	6,302	0	20,640
23.12	Col. Direccion del Norte	0	0	76.54	138.00	0	0	0	0	0	0	0	0	0	0	0	0	0
23.13	Col. Cuauhtemoc	0	0	75.00	100.00	0	0	0	0	0	0	0	0	0	0	0	0	0
23.16	S.P.R. de R.I. Los Huicos	509,438	416,813	90.00	110.00	0	361	60,575	91,944	112,496	39,482	54,085	13,701	18,930	17,127	8,113	0	277,440
23.18	SPR Emiliano Zapata	549,069	431,939	73.68	93.66	141	0	0	97,821	32,466	97,680	70,578	91,611	28,796	12,845	0	0	244,800
24.01	Col. Jalisco	332,468	309,860	111.94	120.00	0	0	0	0	70,648	68,582	58,584	56,271	54,370	1,405	0	0	225,000
24.03	Col. 21 de Marzo III Frac	315,968	296,320	109.04	116.27	0	14,327	87,327	102,791	91,534	114	114	114	0	0	0	0	208,480
24.04	SPR R.I. Maria Elena	472,376	410,762	100.00	115.00	0	0	0	0	0	0	0	0	168,650	242,[illegible]	0	0	285,840
24.05	Mejia Hernandez Felipe	53,467	53,609	124.87	124.54	0	0	10,509	11,253	9,979	7,112	14,543	212	0	0	0	0	40,400
24.08	SPR Leyes de Reforma Cajeme	221,929	220,886	97.4	97.86	0	0	0	0	0	0	0	0	124,020	96,965	0	0	130,800
24.09	Col. 21 de Marzo III Frac	1,429	1,426	101.79	102.00	0	0	518	130	130	130	130	130	130	130	0	0	880
24.10	Com.Ind. San Francisomito	5,565	5,236	95.02	101.00	654	262	131	654	785	1,047	654	393	262	0	393	0	3,200
24.13	SPR de R.I. Avilez Nunez	152,049	138,425	91.95	101.00	0	0	0	29,452	40,055	62,242	6,087	589	0	0	0	0	84,600
24.14	SPR Jacinto Lopez	559,975	501,640	103.02	115.00	0	0	0	17,417	122,953	54,147	105,708	85,877	115,539	0	0	0	349,080
24.15	Col. Jalisco	607,416	515,992	97.64	114.94	0	115	0	0	141,246	90,983	86,842	42,558	142,628	11,617	0	0	358,880
24.18	SPR Heroes del 47	308,223	224,230	77.98	107.19	0	0	1,480	48,842	34,967	53,467	82,144	0	0	0	3,330	0	145,440
24.19	SPR Heroes del 47	29,119	21,680	79.68	107.02	0	0	0	0	19,642	927	1,112	0	0	0	0	0	14,040
24.20	Col. 21 de Marzo III Frac	0	0	125.80	134.83	0	0	0	0	0	0	0	0	0	0	0	0	0
24.23	SPR Heroes del 47	0	0	76.82	101.63	0	0	0	0	0	0	0	0	0	0	0	0	0
24.99	SPR Jacinto Lopez	872,567	793,243	100.00	110.00	0	26,321	63,099	187,494	166,220	101,319	99,336	66,885	82,209	361	0	0	528,000
27.07	Escobar Magdaleno H	21,819	17,346	99.37	125.00	0	11,370	0	5,976	0	0	0	0	0	0	0	0	13,120
33.01	CJN. Juarez No. 24	29,041	26,457	114.75	125.97	645	287	2,125	3,698	4,542	7,291	823	1,430	1,482	2,954	[illegible]	0	20,167
34.06	S.P.R. Jose Maria Morelos	540,160	521,721	128.46	133.00	0	41,302	74,404	155,070	114,811	30,418	46,521	47,117	10,736	746	536	0	419,880
34.07	S.P.R. Jose Maria Morelos	260,087	215,110	110.00	133.00	0	0	0	199	65,805	33,400	64,016	50,696	0	0	394	0	173,120
34.08	S.P.R. Jose Maria Morelos	224	215	117.98	123.00	0	0	215	0	0	0	0	0	0	0	0	0	160
34.09	S.P.R. de R.I. Los Olivos	304,117	274,638	135.46	150.00	0	0	0	176,276	71,216	18,156	6,522	353	0	0	2,115	0	249,280
36.01	Ejido El Ejemplo	335,346	279,012	119.81	144.00	0	0	0	28,920	63,212	88,138	60,595	35,118	0	0	3,030	0	243,120
36.04	Ejido El Ejemplo	4,875	4,402	130.16	144.15	0	0	0	0	4,127	0	0	138	138	0	0	0	3,840
36.05	Ejido El Ejemplo	389,140	353,203	119.81	132.00	13,221	7,512	11,418	54,836	65,052	41,916	51,531	15,474	34,103	35,305	22,836	0	282,120
36.07	Ejido El Ejemplo	4,860	4,673	147.29	153.20	296	0	0	698	611	1,002	705	553	408	0	410	0	4,332
36.99	Ejido El Ejemplo	9,916	7,602	115.00	150.00	0	0	0	0	0	0	0	0	0	4,453	3,149	0	6,900
38.04	Ejido Nueva Creacion Cajeme																	258,960
	TOTALS	59,846,286 m3	41,039,738 m3 = 33,257 acre-feet			174,396	996,882	3,431,953	5,711,809	6,545,990	5,232,230	5,897,506	5,578,371	3,813,786	2,631,204	1,025,612	0	18,864,293

Jan.1994 electrical figures are not yet available,
so Dec.1993 use cannot yet be calculated.
(December use is generally quite low compared to other months.)

The following wells were included because of electricity usage,
even though well depths are not available :

6.20 Ejido Hombres Blancos Pozo #3
6.35 Ejido Hombres Blancos Pozo #1
6.40 L. Internacional Pozo #2
6.42 Ejido Sonoyta Papagos Pozo #2
6.43 Ejido Sonoyta Papagos Pozo #3
11.09 S.P.R. El Cumplimiento
38.04 Ejido Nueva Creacion Cajeme

Figure 63—continued.

SECRETARIA DE AGRICULTURA Y RECURSOS HIDRAULICOS (S.A.R.H.)

RURAL DEVELOPMENT DISTRICT No.139 CABORCA, SONORA

CENTER FOR RURAL DEVELOPMENT ASSISTANCE No.01 SONOYTA, SONORA

"AREAS CULTIVATED THROUGH 1993"

Crops	1982 Area (ha.)	%	1983 Area (ha.)	%	1984 Area (ha.)	%	1985 Area (ha.)	%	1986 Area (ha.)	%	1987 Area (ha.)	%
Corn	261	2.6	16	0.2	69	0.7	78	0.8	106	1.0	182	1.6
Beans	118	1.2	17	0.2	25	0.2	189	1.9	917	9.0	39	0.4
Wheat	2,220	21.8	2,128	20.9	213	2.1	2,247	22.0	4,171	40.9	4,289	38.9
Sesame	51	0.5	346	3.4	319	3.1	117	1.1	174	1.7	549	5.0
Cotton	3,525	34.6	3,481	34.2	5,118	50.2	2,918	28.6	430	4.2	837	7.6
Vegetables	106	1.0	49	0.5	19	0.2	107	1.0	88	0.9	70	0.6
Fruits	639	6.3	1,035	10.2	1,190	11.7	959	9.4	722	7.1	644	5.8
Alfalfa	1,136	11.1	993	9.7	1,052	10.3	704	6.9	552	5.4	686	6.2
Feed	15	0.1	—	—	16	0.2	26	0.3	296	2.9	585	5.3
Sorghum	—	—	2	0.0	—	—	33	0.3	52	0.5	136	1.2
Barley	—	—	20	0.2	—	—	—	—	—	—	10	0.1
Safflower	—	—	—	—	—	—	—	—	—	—	—	—
TOTALS	8,071	79.2	8,087	79.4	8,021	78.7	7,378	72.4	7,508	73.7	8,027	72.8

Crops	1988 Area (ha.)	%	1989 Area (ha.)	%	1990 Area (ha.)	%	1991 Area (ha.)	%	1992 Area (ha.)	%	1993 Area (ha.)	%
Corn	51	0.5	79	0.7	19	0.2	53	0.5	149	1.4	115	1.0
Beans	—	—	25	0.2	100	0.9	111	1.0	4	0.0	10	0.1
Wheat	3,270	29.6	2,860	25.9	1,663	15.1	955	8.7	733	6.6	895	8.1
Sesame	124	1.1	90	0.8	234	2.1	30	0.3	51	0.5	—	—
Cotton	1,812	16.4	1,197	10.9	1,686	15.3	2,560	23.2	951	8.6	1,021	9.3
Vegetables	43	0.4	14	0.1	28	0.3	286	2.6	658	6.0	519	4.7
Fruits	357	3.2	232	2.1	232	2.1	170	1.5	91	0.8	86	0.8
Alfalfa	579	5.2	390	3.5	998	9.0	908	8.2	517	4.7	541	4.9
Feed	684	6.2	156	1.4	336	3.0	66	0.6	30	0.3	—	—
Sorghum	80	0.7	13	0.1	242	2.2	—	—	—	—	—	—
Barley	163	1.5	—	—	—	—	—	—	—	—	—	—
Safflower	13	0.1	178	1.6	—	—	—	—	—	—	10	0.1
TOTALS	7,176	65.1	5,234	47.4	5,538	50.2	5,139	46.6	3,184	28.9	3,197	29.0

The percentages refer to the area under cultivation in relation to the total irrigable area.

Irrigable Area	1982 - 1986	10,191 hectares
	1987 - 1993	11,031 hectares

Figure 64. Crop acreage in Sonoyta Agricultural District, Sonora, 1982–1993.

Table 15. Comparative water usage and crop acreage totals for Sonoyta Agricultural District, Sonora, Mexico, 1989–1993.

Year	Crop Acreage (ha.)	Energy Usage (kWh x 10^6)	Water Withdrawal Based on Static Levels (m^3 x 10^6)	Water Withdrawal Based on Dynamic Levels (m^3 x 10^6)	Water Withdrawal Based on Dynamic Levels (acre-ft)
1989	5,234	42.0	111.6	87.6	71,002
1990	5,538	39.2	115.7	87.6	70,962
1991	5,139	32.8	108.0	75.2	60,910
1992	3,184	18.9	65.4	42.9	34,796
1993*	3,197	19.6	62.8	43.3	35,083

Groundwater

Introduction

The development of groundwater resources was very important in the early days of mining and ranching in ORPI, since surface water is scarce and largely ephemeral in the area. Wells were drilled or dug by hand and reached depths of nearly 60 m . Some attempts to reach water were unsuccessful, including NPS test wells in the Valley of the Ajo. Most of these wells are now dry, caved in or sealed off to humans or wildlife access. Historically, some well depths were checked intermittently by park rangers, but no monitoring program existed.

In the 1960s, the Mexican government promoted irrigated agriculture on land adjacent to the ORPI border. This prompted concern over possible impacts, including (1) disruption of the flow at Quitobaquito Springs, (2) lowering of water levels in the Lukeville area, and (3) long-term effects on the water supply at monument headquarters. Other impacts related to groundwater levels include land subsidence and loss of riparian habitats. Because of these possible problems, inventory and monitoring were conducted in the 1970s and 1980s by NPS and the U.S. Geological Survey (USGS). Resource management staff continue to contribute to this effort by measuring depth-to-water levels in monument wells 4 times a year.

Program History

In response to groundwater concerns, the NPS Water Resources Division conducted a well and spring inventory at ORPI in the early 1970s and began a program of measuring water levels at selected wells to establish seasonal and long-term trends. A control structure was installed at Quitobaquito springs and monument personnel were trained to collect flow data.

In 1981, a program of regular monitoring of groundwater depth in wells was initiated. Fourteen wells were monitored by USGS, under contract to NPS, or by park staff (6 wells are monitored by both NPS and USGS). Three observation wells were drilled by the USGS in October 1988 to augment the data provided by existing historic wells on the border.

1994 Monitoring Activities

Depth-to-water measurements were made at 11 wells in January, April, July, and October. Monitoring at 2 wells, Salado and Dowling, was discontinued due to their collapse.

Methods

Depth-to-water is measured from a fixed reference point using a steel tape. The measurements are recorded in a field book and later entered into a Lotus spreadsheet.

Results

All the wells were checked on schedule in 1994. Figures 65–74 and Table 16 are provided showing water levels, well depths, and deviation from average seasonal water levels for all but the USGS test wells.

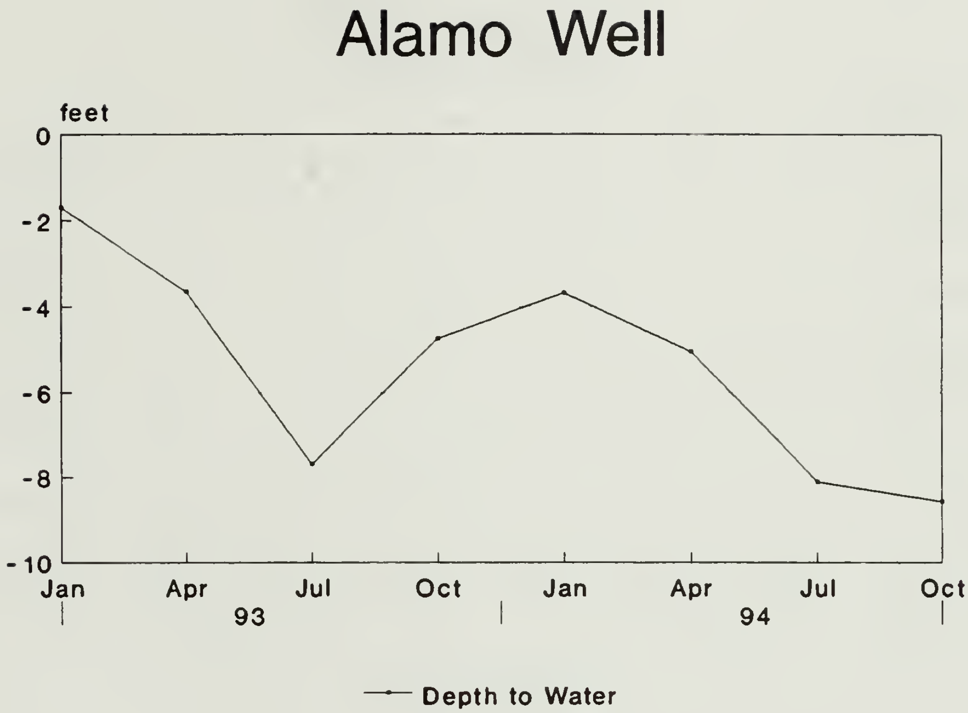


Figure 65. Alamo well depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

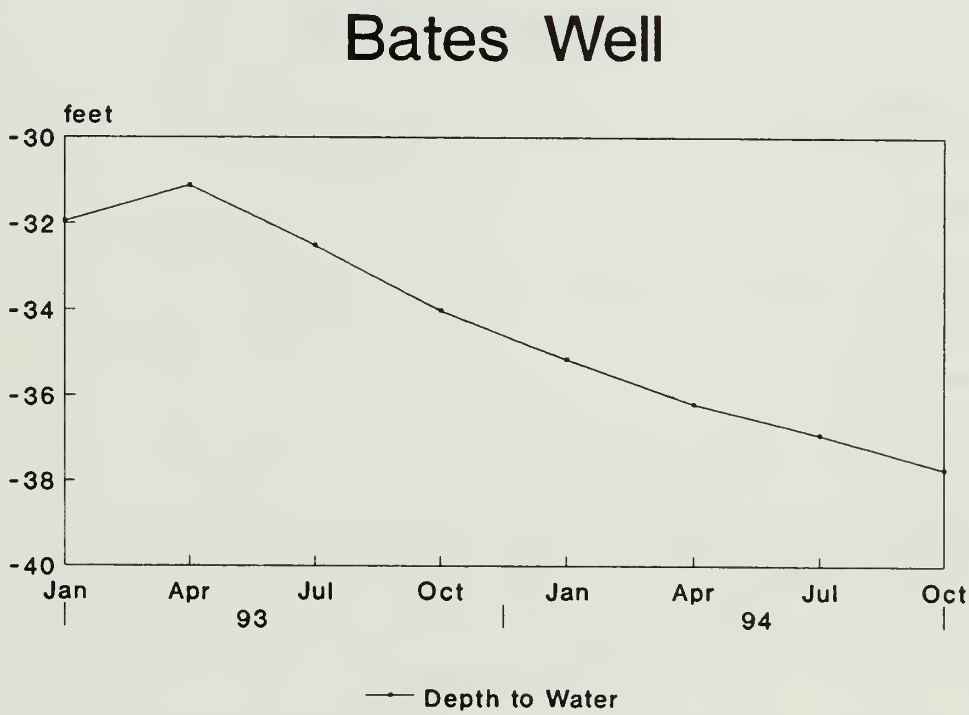


Figure 66. Bates well depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

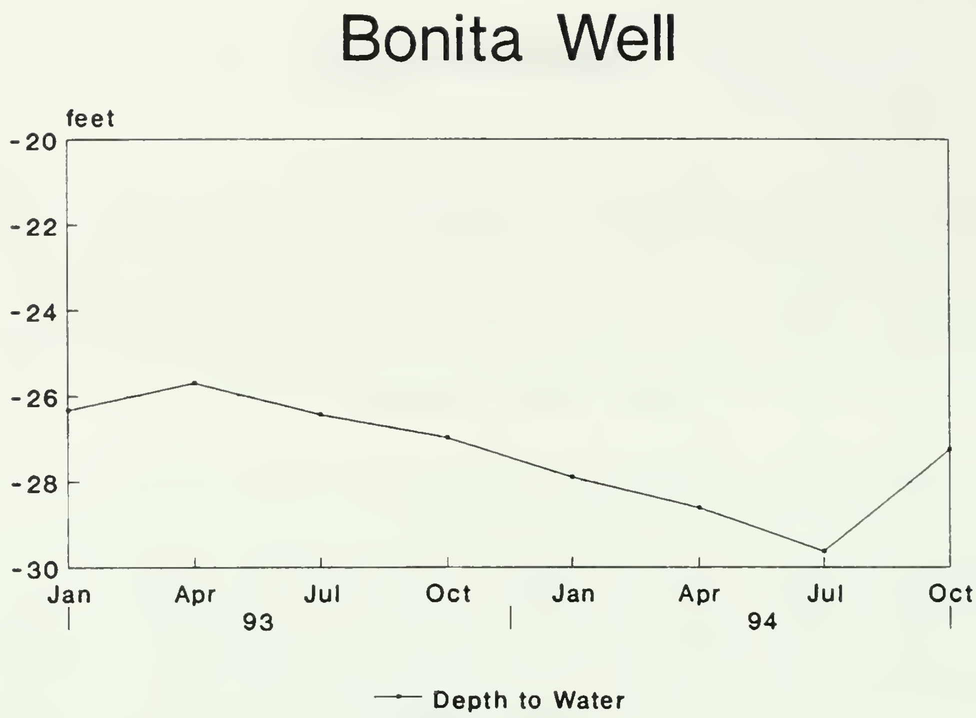


Figure 67. Bonita well depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

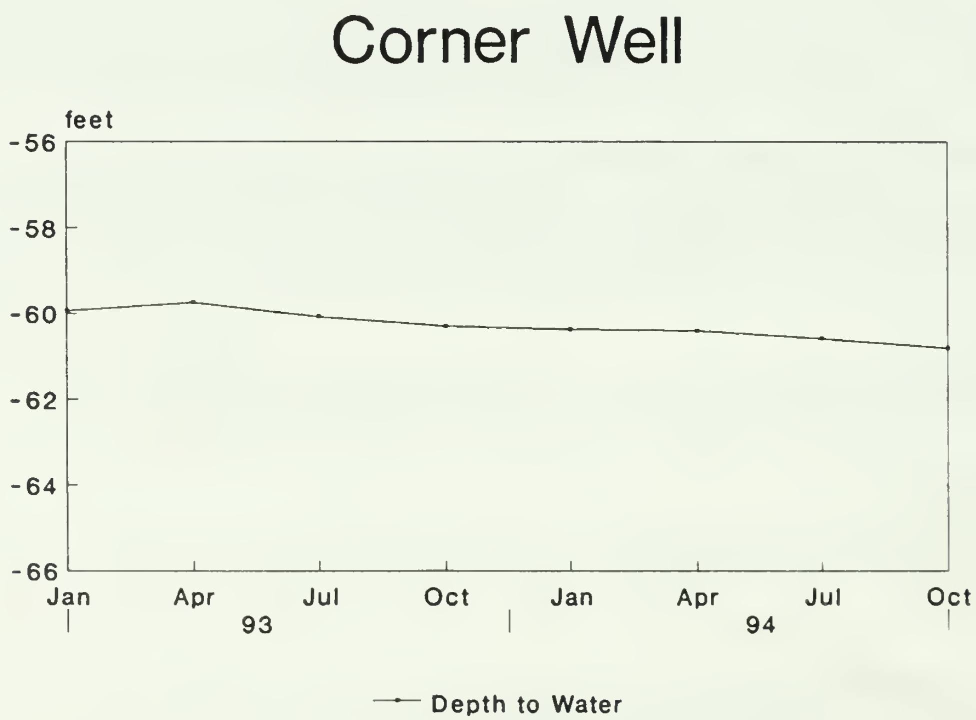


Figure 68. Corner well depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

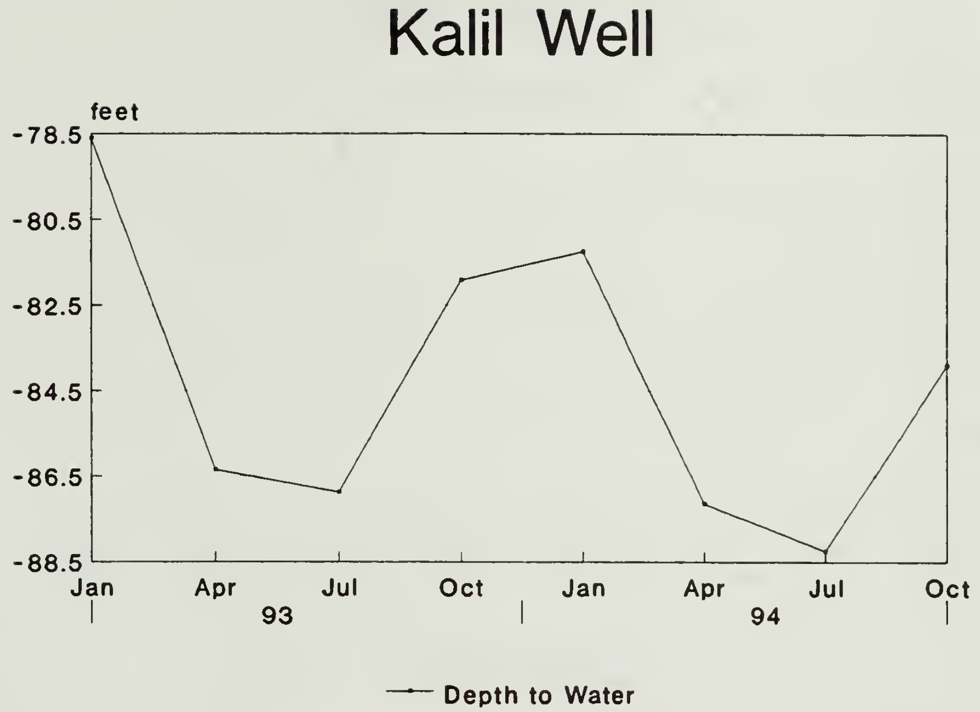


Figure 69. Kalil well depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

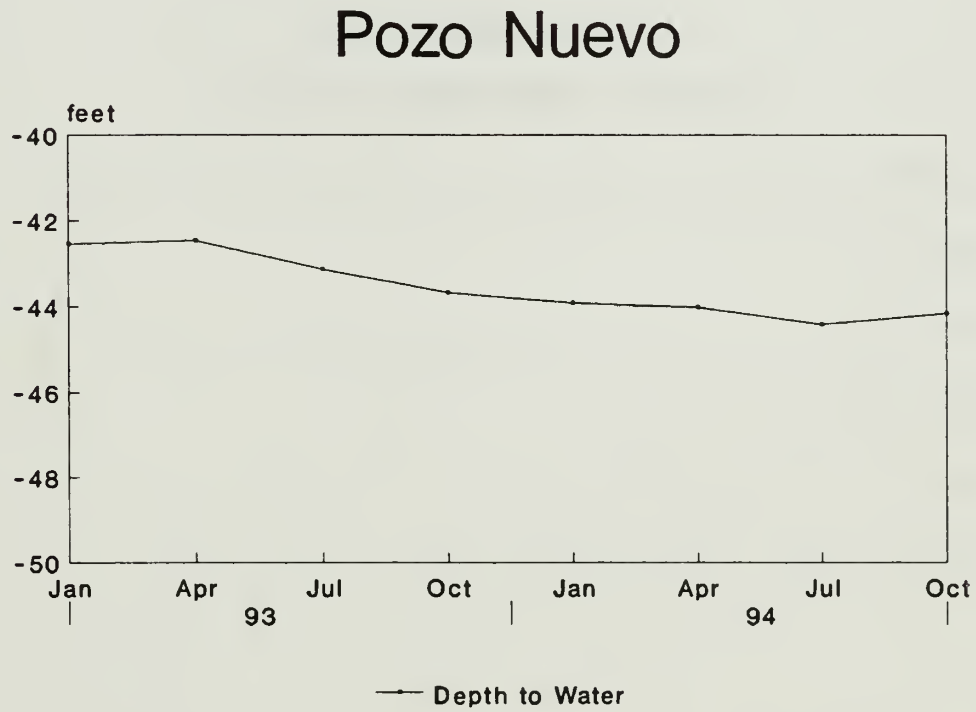


Figure 70. Pozo Nuevo well depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

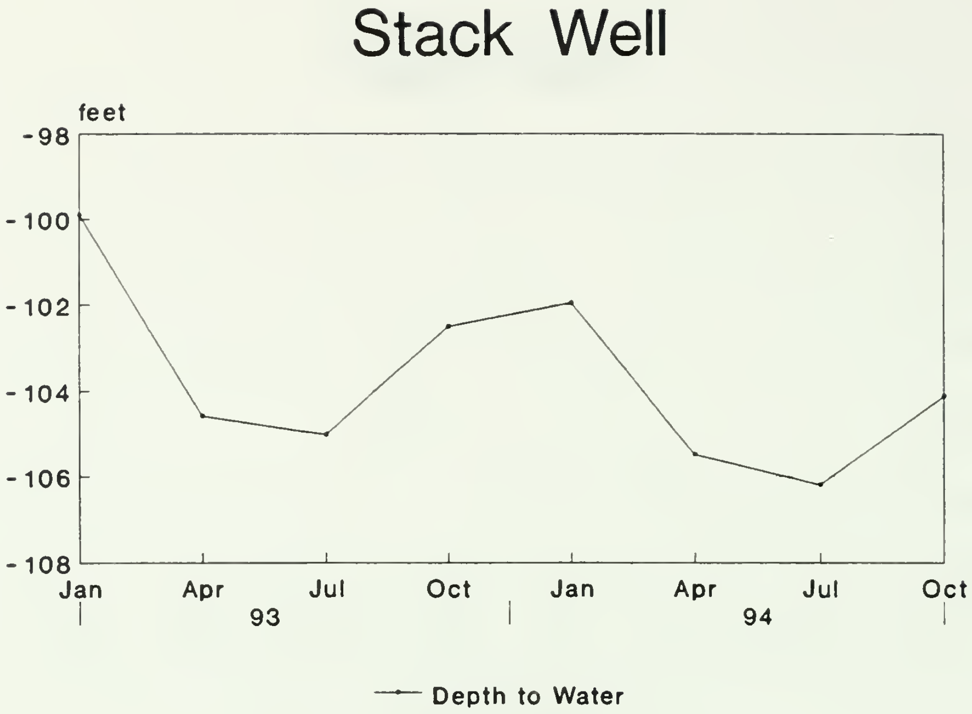


Figure 71. Stack well depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

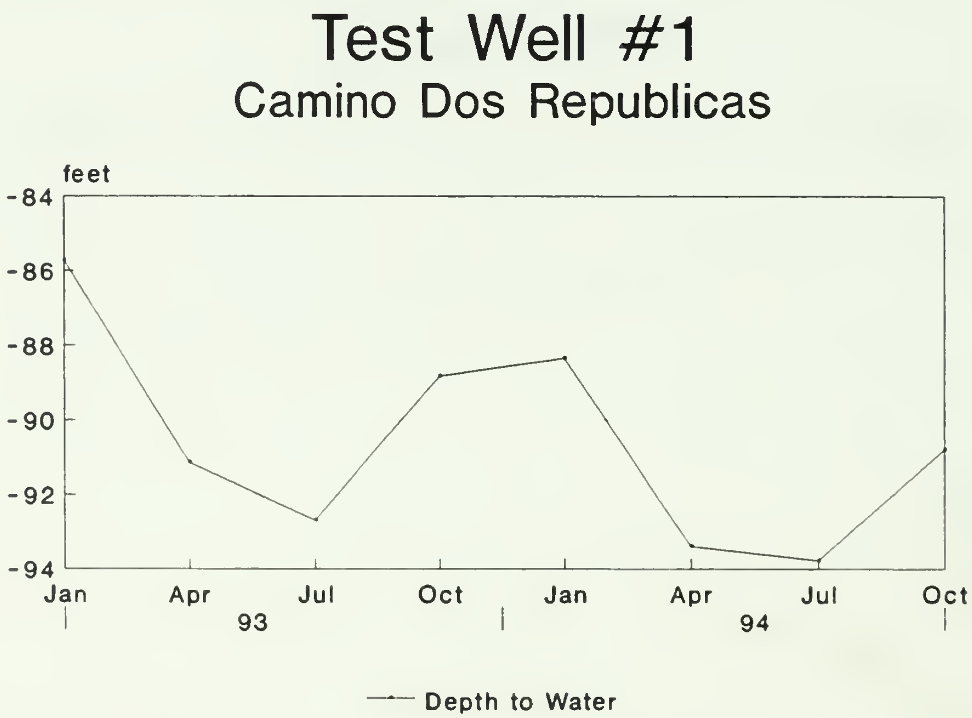


Figure 72. Test Well #1 depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

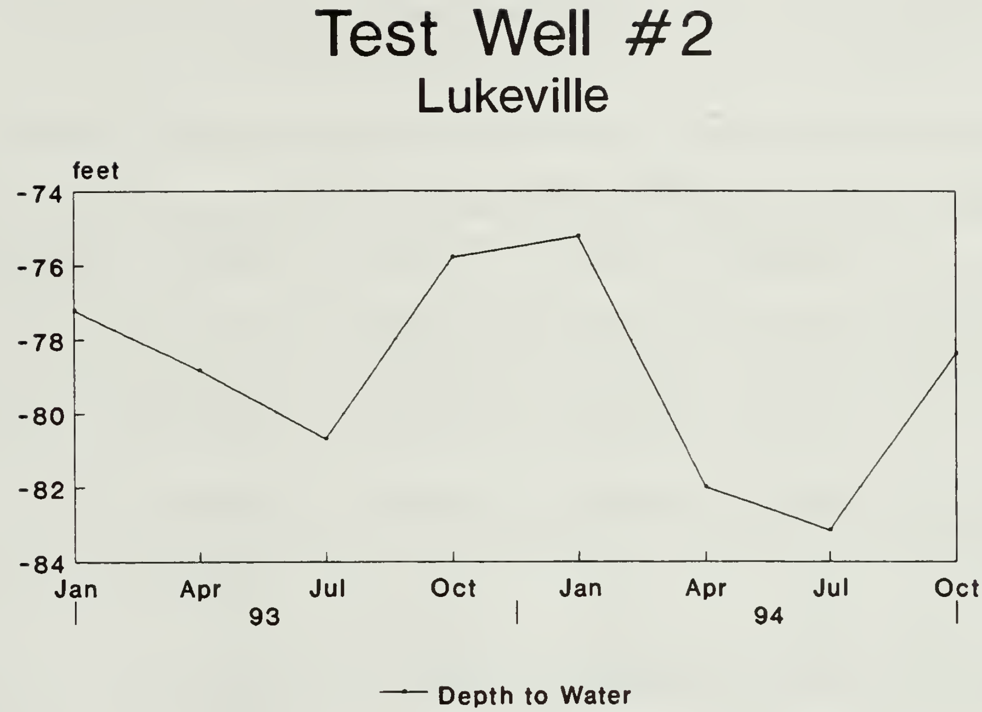


Figure 73. Test Well #2 depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

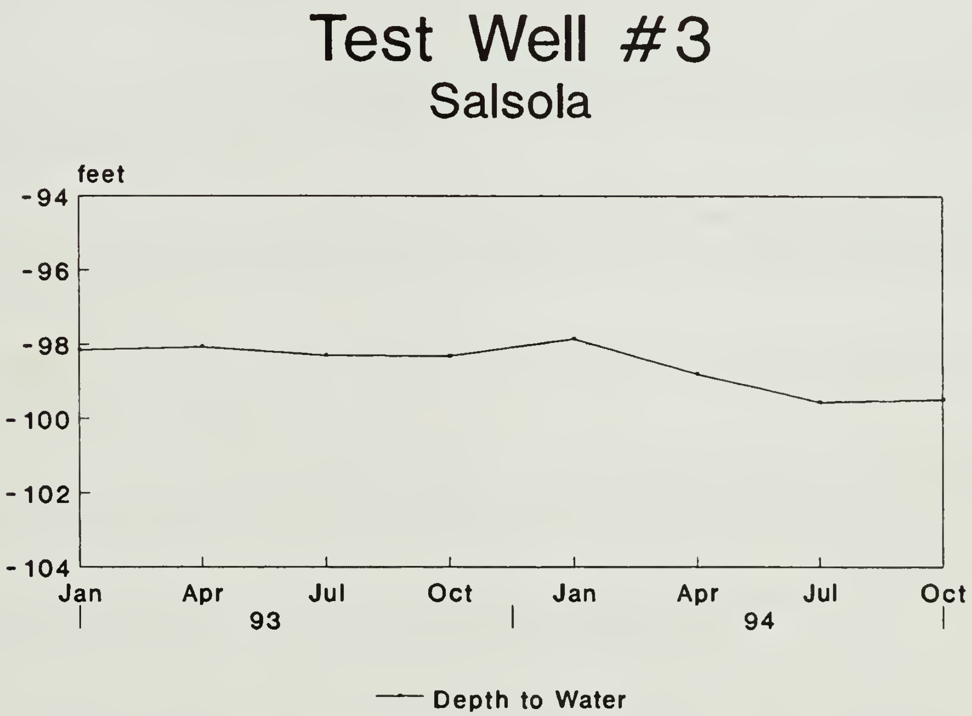


Figure 74. Test Well #3 depth, Organ Pipe Cactus National Monument, Arizona, 1993–1994.

Table 16. Depth-to-water measurements (in feet) at wells in Organ Pipe Cactus National Monument, Arizona, 1994. Approximate depth of hole also included.

	Depth to water				
Well	January	April	July	October	Approximate Depth of hole
Alamo	3.68	5.04	8.1	8.56	17
Bates	35.15	36.2	36.91	37.72	67
Bonita	27.89	28.6	29.62	27.25	36
Corner	60.37	60.41	60.58	60.81	97
Hocker	16.95	16.85	dry	dry	18
Kalil	81.25	87.13	88.24	83.9	187
Nuevo	43.91	44.01	44.41	44.15	134
Stack	101.95	105.49	106.19	104.13	206

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The cover art was rendered by Ami Pate, a biological technician at Organ Pipe Cactus National Monument.

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